

Water Quality in the Apalachicola-Chattahoochee- Flint River Basin

Georgia, Alabama, and Florida, 1992–95



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- The authors gratefully acknowledge the cooperation of numerous property owners who provided access to sampling locations on their land. We also wish to acknowledge the numerous organizations and individuals who have helped distribute our publications to the interested public. Appreciation also is extended to the following personnel of the U.S. Geological Survey: James B. McConnell for his tireless efforts to provide technical review of many of the NAWQA reports; Maurice D. Winner for his thoughtful reviews and approval of untried report products; and finally Caryl J. Wipperfurth, and Carolyn A. Casteel of the Georgia District publications unit for their timeliness and attention to quality. Photographs without credit listed were taken by one of the report authors.

- *Front Cover*—Photograph of downtown, Atlanta, Ga., March 30, 1997, *reprinted* from Georgia Aerial Surveys, Inc., and published with permission.

- *Back Cover*—Photographs of Horse Trough Falls in the headwaters of the Chattahoochee River (*photograph* by Alan M. Cressler, USGS); Morgan Falls Dam on the Chattahoochee River, built in 1904 to power trolley cars in downtown Atlanta; and the Apalachicola Bay Estuary, located at the mouth of the ACF River Basin—the bay is prized for commercial fishing and oyster and shrimp harvesting.

From its headwaters on the forested slopes of the Blue Ridge Mountains, the Chattahoochee River begins its course toward the Gulf of Mexico. Along the way, the river flows through poultry production areas of northern Georgia, the growing metropolis of Atlanta, and numerous reservoirs surrounded by rolling forests and farmlands of Georgia and Alabama. The Flint River begins beneath the runways of Atlanta's Hartsfield Airport, but is quickly surrounded by rolling forests and farmlands, as well. Where Georgia, Alabama, and Florida meet, the Flint and Chattahoochee Rivers join to form the Apalachicola River. The Apalachicola River finishes the journey to the Gulf of Mexico winding its way through large expanses of coastal forests of the Florida Panhandle.

The seemingly untouched headwaters and mouth of this river system give few hints to its role as a vital source of water for drinking, generating power, recreation, assimilating wastes, irrigating crops, transportation, and producing seafood. The action is in between.

FOR ADDITIONAL INFORMATION ON THE NATIONAL WATER-QUALITY ASSESSMENT (NAWQA) PROGRAM:

Apalachicola–Chattahoochee–Flint Study Unit, contact:

District Chief
U.S. Geological Survey
Water Resources Division
3039 Amwiler Road, Suite 130
Atlanta, GA 30360–2824

Chief, NAWQA Program
U.S. Geological Survey
Water Resources Division
12201 Sunrise Valley Drive, M.S. 413
Reston, VA 20192

Information on the NAWQA Program is also available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resources Locator (URL):
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The Apalachicola–Chattahoochee–Flint Study Unit's Home Page is at URL: <http://wwwga.usgs.gov/nawqa>

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By Elizabeth A. Frick, Daniel J. Hippe, Gary R. Buell,
Carol A. Couch, Evelyn H. Hopkins, David J. Wangsness,
and Jerry W. Garrett

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CONTENTS

National water-quality assessment program	1
Summary of major issues and findings	2
Environmental setting.....	4
Study design and data collection.....	6
Hydrologic conditions.....	8
Water-quality conditions during flooding caused by Tropical Storm Alberto, July 1994	9
Major issues and findings:	
Pesticides in streams	10
Pesticides in ground water	13
Nutrients and suspended sediment in streams	14
Nutrients in ground water	17
Trace elements and organic compounds in bed sediment	18
Historical trends in water quality determined from reservoir cores	21
Biological indicators of water quality	24
Water-quality conditions in a national context.....	26
Summary of compound detections and concentrations	30
References	35
Glossary.....	36

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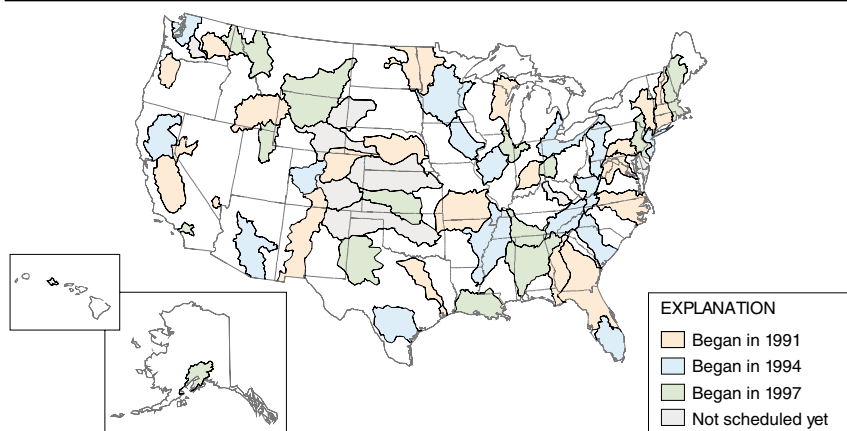
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Knowledge of the quality of the Nation's streams and aquifers is important because of the implications to human and aquatic health and because of the significant costs associated with decisions involving land and water management, conservation, and regulation. In 1991, the U.S. Congress appropriated funds for the U.S. Geological Survey (USGS) to begin the National Water-Quality Assessment (NAWQA) Program to help meet the continuing need for sound, scientific information on the areal extent of the water-quality problems, how these problems are changing with time, and an understanding of the effects of human actions and natural factors on water-quality conditions.

The NAWQA Program is assessing the water-quality conditions of more than 50 of the Nation's largest river basins and aquifers, known as Study Units. Collectively, these Study Units cover about one-half of the United States and include sources of drinking water used by about 70 percent of the U.S. population. Comprehensive assessments of about one-third of the Study Units are ongoing at a given time. Each Study Unit is scheduled to be revisited every decade to evaluate changes in water-quality conditions. NAWQA assessments rely heavily on existing information collected by the USGS and many other agencies as well as the use of nationally consistent study designs and methods of sampling and analysis. Such consistency simultaneously provides information about the status and trends in water-quality conditions in a particular stream or aquifer and, more importantly, provides the basis to make comparisons among watersheds and improve our understanding of the factors that affect water-quality conditions regionally and nationally.

This report is intended to summarize major findings that emerged between 1992 and 1995 from the water-quality assessment of the Apalachicola–Chattahoochee–Flint River Basin Study Unit and to relate these findings to water-quality issues of regional and national concern. The information is primarily intended for those who are involved in water-resource management. Indeed, this report addresses many of the concerns raised by regulators, water-utility managers, industry representatives, and other scientists, engineers, public officials, and members of stakeholder groups who provided advice and input to the USGS during this NAWQA Study-Unit investigation. Yet, the information contained here may also interest those who simply wish to know more about the quality of water in the rivers and aquifers in the area where they live.

Robert M. Hirsch

Robert M. Hirsch, Chief Hydrologist

NAWQA Program helps U.S. Environmental Protection Agency (USEPA) implement new pesticide law

Since the enactment of the Food Quality Protection Act (FQPA), passed in August 1996, USEPA has been required to factor potential exposures to pesticides through drinking water into already complex procedures used to set pesticide "tolerance levels" in foods.

Incorporating potential drinking-water exposures into the pesticide tolerance-setting process has presented USEPA with many scientific challenges including:

- What reliable data are available on pesticide concentrations in surface and ground water in the U.S.? How do these concentrations vary with location and time?
- How can USEPA account for the considerable geographic variability in geology, hydrology, land use, and agronomic practices in estimating profiles of pesticide drinking water exposures in various regions across the U.S.?
- What "real world" data are available to evaluate and improve computational models that USEPA uses to estimate pesticide drinking-water residues for new pesticides entering the market?
- What types of surface- and ground-water monitoring should USEPA require pesticide makers to conduct after new pesticides (or significant changes in use areas or practices) are approved to verify that actual pesticide levels do not exceed those estimated through USEPA's screening procedures?

Building on many years of productive collaboration between USEPA and USGS, the NAWQA Program marshaled a wide range of its data and expertise to help USEPA address these and other questions.

We do not have all of the answers yet by any means, but we in USEPA who are charged with implementing this part of the new FQPA are greatly impressed with the knowledge and expertise contributed by NAWQA Program scientists and managers to assist USEPA in addressing these questions. This collaboration has been facilitated by NAWQA's dedicating one of its senior hydrologists to work with USEPA to help both organizations better understand how NAWQA data and tools can help USEPA.

USEPA's Office of Pesticide Programs is a very satisfied "customer" of USGS and NAWQA water-resources programs.

Joseph J. Merenda, Director
Environmental Fate and Effects Division
Office of Pesticide Programs
U.S. Environmental Protection Agency

SUMMARY OF MAJOR ISSUES AND FINDINGS IN THE APALACHICOLA–CHATTAHOOCHEE–FLINT (ACF) RIVER BASIN

PESTICIDES IN STREAMS AND GROUND WATER

- Pesticide concentrations in stream-water samples from all major land uses in the Study Unit were less than current drinking-water standards and guidelines for lifetime exposure. However, concentrations of one or more insecticides in streams draining areas of urban and suburban land use often exceeded chronic exposure criteria for protection of aquatic life. The highest measured pesticide concentrations in stream-water samples generally coincided with the growing season when most pesticides are applied. However, some pesticides were present at lower concentrations throughout the year (pages 10–11).
- Herbicides that provide selective preemergence weed control are the predominant type of pesticide detected in small streams draining agricultural areas and in large rivers located in the Coastal Plain. Small streams draining urban and suburban areas, and large rivers located downstream from urban areas contain a more diverse mixture of pesticides including compounds used for insect control, selective preemergence and postemergence weed control, and nonselective weed control (page 10).
- Storm runoff carries much of the total quantity of pesticides present in streams in both agricultural and urban areas of the Study Unit. However, the quantities of pesticides transported by streams are low relative to the quantities applied, because pesticides are retained in the soil, degraded, or transported by other pathways (page 12).
- Pesticide (and VOC) concentrations in ground-water samples generally were less than U.S. Environmental Protection Agency (USEPA) drinking-water standards and guidelines. However, in water samples from shallow ground water in Metropolitan Atlanta 14 percent of dieldrin concentrations exceeded drinking-water guidelines (and 5 percent of benzene and PCE concentrations exceeded drinking-water standards). These exceedances indicate a potential water-quality concern for developing future public-drinking water supplies in the fractured-rock aquifer underlying Metropolitan Atlanta. Pesticides were detected least frequently in water samples from shallow ground-water monitoring wells located adjacent to cropland and most frequently in samples from springs and wells located in the recharge area to the Upper Floridan aquifer, a karst aquifer that is susceptible to contamination (pages 13 and 29).
- Many pesticides detected in ground-water samples either are no longer in use or were in much greater use a decade or more prior to the sampling period. Because ground water moves slowly through the subsurface, pesticides currently detected in ground water lag changes in crop production and pesticide use patterns (page 13).

NUTRIENTS IN STREAMS AND GROUND WATER

- Nutrient concentrations and yields in streams within the ACF River Basin are generally highest in tributaries draining watersheds predominated by poultry, urban, and suburban land use, particularly during stormflow conditions, and in the Chattahoochee River downstream from Atlanta. USEPA criteria for total-phosphorus was most often exceeded during stormflow conditions at each of these settings. In general, lower nutrient concentrations and yields are indicative of good water quality in watersheds predominated by cropland and forests, the Chattahoochee River upstream from Atlanta, and the Apalachicola River near its mouth (pages 14–16).
- In tributary streams studied, more than 60 percent of most nutrient yield occurs during stormflows. In the urban watershed, which has the highest percentage of impervious area, more than 80 percent of runoff and nutrient yields occur during stormflows. The predominance of stormflow transport is indicative of nonpoint sources of nutrients (pages 15–16).
- Improvements to wastewater-treatment facilities and restrictions on the use of phosphate detergents have significantly decreased phosphorus loads in municipal-wastewater effluent discharged to the Chattahoochee River near and downstream from Atlanta and in reservoir sediments downstream from Atlanta. However, point sources of phosphorus from wastewater-treatment facilities to the Chattahoochee River and overflows from sanitary and combined sewer overflows to tributaries contribute to exceedances of USEPA criteria for total phosphorus. Nonpoint sources of phosphorus continue to increase throughout Metropolitan Atlanta as indicated by data upstream from Atlanta (page 16).
- Although nitrate generally is present in low concentrations in ground water in most urban and agricultural areas and in the Upper Floridan aquifer, nitrate concentrations only rarely exceed the drinking-water standard. In the major crop-producing areas of the ACF River Basin, clay-rich upland soils and extensive flood plains reduce the risk of nitrate contamination of ground water and streams, respectively. Nitrate concentrations in tile drains are very high, and where tile drains are present, they represent an important pathway for transport of nitrate and other agricultural chemicals to streams (page 17).

TRACE ELEMENTS AND ORGANIC COMPOUNDS IN BED SEDIMENTS AND RESERVOIR CORES

- The largest enrichments of trace elements and the highest concentrations of organic compounds in bed sediments are in the urban and suburban watersheds draining portions of Metropolitan Atlanta and Columbus, and in main-stem and reservoir settings on the Chattahoochee River downstream from Atlanta. Concentrations of mercury, cadmium, lead, and zinc in bed sediments of these urban and suburban watersheds increased in direct proportion to the amount of industrial land and

SUMMARY OF MAJOR ISSUES AND FINDINGS IN THE APALACHICOLA–CHATTAHOOCHEE–FLINT (ACF) RIVER BASIN

transportation corridors in these watersheds. Much of the current pollutant load of trace elements and organic compounds is from stormwater runoff from impervious surfaces in urban and suburban areas and local and regional industrial emissions (pages 18–20).

- In reservoirs located downstream from urban areas, concentrations of lead, zinc, chromium, and copper in sediment cores reached maximum concentrations during the late 1960's and mid-1970's in response to urban growth and industrial development, but have declined as a result of compliance with environmental laws enacted during the mid-1970's. This is particularly true for lead. Atmospheric sources of lead peaked in 1972, when use of leaded gasoline peaked, and have continued to decline to present. Concentrations of lead in cores from reservoirs downstream from Atlanta closely mirror changes in atmospheric sources and related storm-runoff sources of lead (page 22).
- Concentrations of organochlorine insecticides, particularly DDT and chlordane, and PCB's in reservoir cores correlate with regional use patterns. Although, concentrations of these compounds have declined significantly since being banned, they continue to be present in sediments deposited as recently as 1994. The slow rate of decline of chlordane and PCB concentrations in sediments deposited in West Point Lake indicate that fish-consumption advisories in the Chattahoochee River downstream from Metropolitan Atlanta may continue into the future (page 23).

BIOLOGICAL INDICATORS OF WATER QUALITY

- Within the Piedmont, the health and composition of fish communities are best in streams draining watersheds predominated by forested land use; followed by streams draining watersheds predominated by poultry and suburban land use. Streams draining watersheds predominated by urban land use have severely degraded fish communities (page 24).
- The macroinvertebrate status of streams draining watersheds predominated by poultry and forest land use were relatively good on the basis of the abundance of pollution-sensitive insects. High stormflows, poor habitat, and the presence of chemical contaminants such as insecticides, contribute to severely degraded macroinvertebrate communities in streams draining watersheds predominated by suburban and urban land use (page 24).

Although urban and suburban land use accounts for only 5 percent of the ACF River Basin, it has the most important effect on stream-water quality. The intensity of the land-use effect on water quality varies in proportion to various measures of urbanization such as impervious area, population density, and percent industrial and transportation land use. As the percentage of urban land use increases within a watershed, nutrients, pesticides, trace elements, and organic compounds are more prevalent and occur at higher concentrations in streams. Watersheds in the Piedmont with higher population densities generally are drained by streams dominated by a few species of pollution tolerant, mostly non-native fishes, indicating poorer biological condition and potentially poorer water quality. Data indicate that the continued urbanization of forested and pasture land surrounding Metropolitan Atlanta are likely to be accompanied by increasing detrimental effects on water quality in area streams, including the area's source of drinking water (pages 5, 10–12, 14–16, and 18–25).

In the Coastal Plain of the ACF River Basin, cropland and silvicultural land in upland areas are separated from streams by relatively undisturbed riparian flood-plain and wetland habitats. This is in contrast to many intensively farmed areas of the United States where wetlands have been drained, channelized or filled, and little or no riparian buffers remain between cropland and streams. Several water-quality implications that can partially be attributed to these wetland buffer areas to streams include (1) fewer pesticides detected and lower pesticide and nutrient concentrations in streams than in other areas of the Nation, (2) lower nitrate concentrations in ground water underlying forested flood plains than in ground water underlying upgradient cropland, and (3) reduced disturbance of fish communities during and after large floods (pages 5, 9, 11, 13, 17, and 25).

Despite widespread alteration of the ACF River Basin environment, the basin is noteworthy for its remaining biological diversity and support of commercial fisheries for oysters, shrimp, blue crabs, and a variety of fin fish in Apalachicola Bay (page 4).

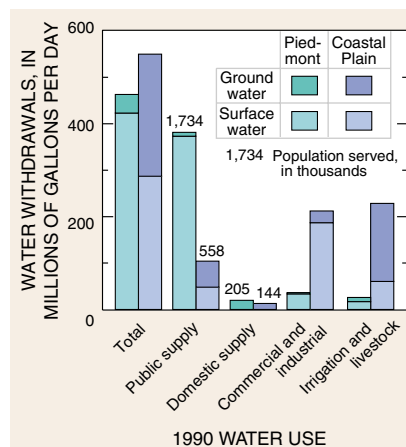
ENVIRONMENTAL SETTING

The ACF River Basin covers approximately 20,000 square miles in the Blue Ridge, Piedmont, and Coastal Plain Physiographic Provinces. The Chattahoochee and Flint Rivers converge at Lake Seminole to form the Apalachicola River, which flows into Apalachicola Bay and the Gulf of Mexico. Basin hydrology, water quality, and aquatic ecosystems are influenced by 16 main-stem reservoirs (13 of which are on the Chattahoochee River), 14 associated hydropower operations, and dredged navigational channels. The reservoirs and dams transform riverine environments into lacustrine environments, impede migration of many aquatic species, and trap transported sediment and sediment-bound contaminants.

Physiography, climate, and hydrology in the ACF River Basin provide natural conditions that support a rich

and abundant diversity of plants and animals. Despite widespread alteration by people, the basin's environment is noteworthy for its remaining biological

diversity and support of commercial fisheries for oysters, shrimp, blue crabs, and a variety of fin fish in Apalachicola Bay (Couch and others, 1996).



Surface-water quality in the Piedmont of the ACF River Basin is of utmost importance because surface water provides about 93 percent of public water supplied to more than 1.7 million people. Rapidly spreading urban development and poultry production in headwater watersheds create added stresses in maintaining sufficient surface-water supplies of good quality.

In the Coastal Plain, ground water provides more than 50 percent of public-water supply and more than 70 percent of irrigation water. Forty-four percent of all ground water used within the basin was from the Upper Floridan aquifer, a karst limestone aquifer that is susceptible to contamination.

Data from: <http://h2o.usgs.gov/public/watuse>



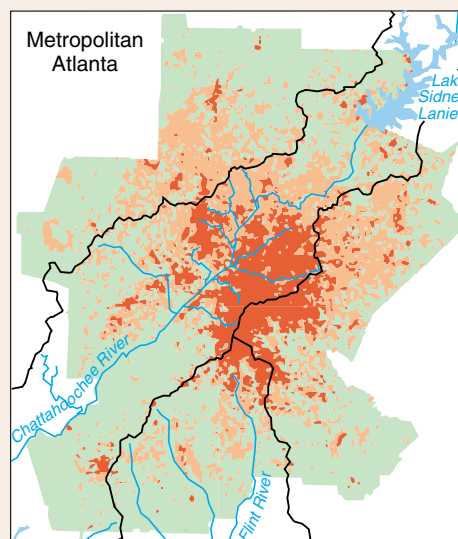
Forest land is the predominant land use in the ACF River Basin and consists mainly of second-growth hardwoods and planted pine. Agricultural land is used for poultry production and pasture in the headwaters and for cropland in the Coastal Plain. Most wetlands are forested and located in flood plains of the Flint and Apalachicola Rivers and their tributaries.

Although urban and suburban land use accounts for only 5 percent of the basin, it has the most significant effect on stream-water quality. Metropolitan Atlanta, the largest and fastest growing metropolitan area in the Southeast, is in the basin's headwaters.

EXPLANATION

Land use—Number is percentage of ACF River Basin

- Urban and suburban, 5 percent
- Agriculture—Includes Piedmont poultry and Coastal Plain cropland, 29 percent
- Forest, 58 percent
- Forested wetland, 5 percent
- Water, 3 percent



Metropolitan Atlanta suburbs continue to expand into the headwaters of the Chattahoochee River, the region's main source of drinking water. Population in the 13-county area (shown to the left) increased 97 percent from 1970 to 3.1 million people in 1995; land area devoted to residential, commercial, and other urban uses more than tripled during the same period.

EXPLANATION

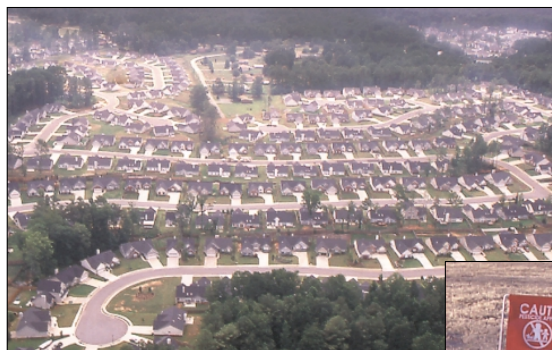
Land use

- Urban area as of mid-1970's
- Urban area developed from mid-1970's to 1995
- Other land use, predominantly forested

Data from U.S. Geological Survey, 1977–80; U.S. Bureau of the Census, 1991; Atlanta Regional Commission, digital data, 1995; <http://www.census.gov/population/www/estimates/countytyp.html>



Urban land use within the Study Unit is defined as dense commercial areas and transportation networks associated primarily with the city of Atlanta. Urban watersheds contain substantial impervious areas that are connected to streams by storm sewers. Streams also receive inputs from combined sewers and leaking or overflowing sanitary sewers. Chemical and microbial contaminants from point and nonpoint sources are the primary water-quality issues within the urban watersheds.



Suburban land use within the Study Unit is defined as established and developing residential areas, associated commercial areas, and transportation networks. It differs from urban land use by the amount of impervious land cover and the lack of known point sources but has the same water-quality issues of contaminants from nonpoint sources.



Since the 1930's, large areas of agricultural land in the Piedmont have been abandoned and have reverted to forests. The remaining agricultural land currently is used for **poultry** production and livestock grazing. Nutrient inputs from poultry litter applied to sloping pasture land and soil erosion are water-quality issues in the headwaters of the Chattahoochee River.



Unlike parts of the United States where large, continuous tracts of land often are farmed to streambanks, **cropland** in the ACF River Basin generally is limited to well-drained upland areas. The long growing season and center-pivot irrigation support a broad range of cash crops and several plantings of some crops on the same fields during the year. Cropland commonly is bordered by extensive **forested wetlands** (inset). In this study, cropland was further subdivided into areas underlain by clastic deposits (sands and shales) and carbonate bedrock (karst) to investigate any differences in water quality that might be attributed to differences in hydrogeology. Excess nutrients and pesticides in ground water and streams are the primary water-quality issues within this land use. (Photograph of cotton field is by L. Elliott Jones, USGS.)



Most **forested** land in the ACF River Basin is silvicultural land owned and managed by individuals or corporations for pulp and lumber production. These mostly second-growth forests are the best available representation of background water-quality conditions in the Study Unit. Erosion, sedimentation, and release of nutrients following timber harvests are the primary water-quality issues in these forested watersheds. (Photograph of Chattahoochee National Forest is by Alan M. Cressler, USGS.)



STUDY DESIGN AND DATA COLLECTION

The primary objectives of NAWQA's ACF River Basin study were to document and describe natural and human influences on water quality and the health of aquatic ecosystems in the basin. A nested monitoring network was designed to maximize understanding of spatial and temporal variability of water quality among various physiographic, hydrogeologic, and land-use settings within the basin (Wangness, 1997). Additional information about the study design, the water-quality and quality-control data, and results are available on the Internet at: <http://www.gsa.usgs.gov/nawqa/>.

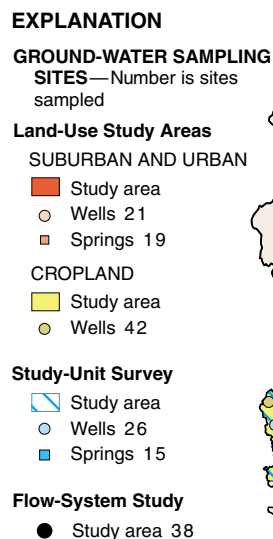
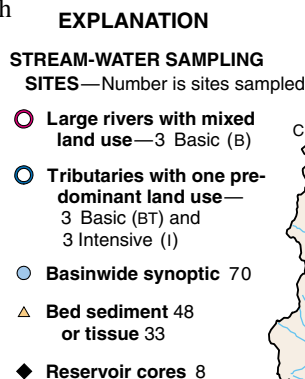
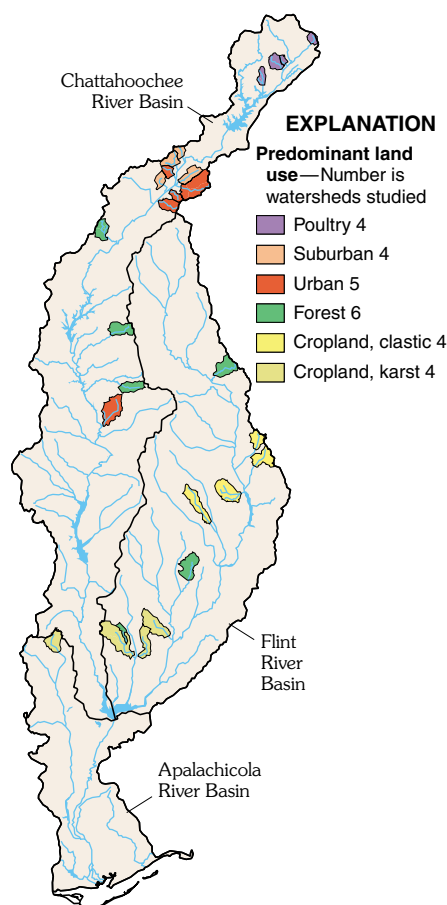
Land-Use Effects on Stream Quality

The sampling network was designed to characterize the effects of land use on stream quality at various scales and physiographic settings. Water chemistry, community-assemblage (fish and invertebrates), habitat, bed-sediment, aquatic-organism tissue,

and reservoir-core data were used as indicators of stream quality. Basic Fixed Sites on large rivers were upstream and downstream from Atlanta and near the mouth of the Apalachicola River. Basic and Intensive Fixed Sites were chosen on tributaries that represent effects of poultry, suburban, urban, forest, and cropland, respectively. Basinwide synoptic sites were located within watersheds with similar predominant land uses, in larger tributaries with mixed land uses, and along the three main-stem rivers. Focused synoptics were conducted to evaluate stream quality in relatively small areas. Bed-sediment and aquatic-organism tissue sites are fewer in number but have a similar distribution to basinwide synoptic sites. Reservoir cores were collected and analyzed from all major reservoirs (page 21).

Land-Use Effects on Ground-Water Quality

The ground-water network was designed to characterize the effects of land use on ground-water quality at various scales and hydrogeologic settings. Land-Use Studies characterized shallow ground water underlying predominantly suburban and urban land use in Metropolitan Atlanta and underlying cropland in the Coastal Plain. The Study-Unit Survey characterized ground-water quality in the Upper Floridan aquifer, the most used aquifer within the ACF River Basin. The Flow-System Study was located in the Lime Creek watershed, a predominantly agricultural basin. Wells, tile drains, and springs were sampled to examine the fate of agricultural chemicals in ground water.



Study component	Objectives and brief description	Number of sites	Frequency sampled	Constituents sampled ^{1/}
Land-use effects on stream quality				
Basic Fixed Sites— Large rivers with mixed land use	Measure concentrations and estimate loads (1) in the Chattahoochee River upstream and downstream from Metropolitan Atlanta to better understand suburban and urban inputs to the river; and (2) near the mouth of the Apalachicola River to better understand outflow from the basin and inflow to the Apalachicola Bay.	3	monthly, (March 1993 through Sept. 1995)	1, 6, 7, (8), 9, 11-15, (16)
Basic and Intensive Fixed Sites— Tributaries with one predominant land use	Measure concentrations and estimate loads in 18- to 105-square-mile watersheds having a predominant land use: poultry, suburban, urban, forest, or cropland. Use community-assemblage and habitat data as indicators of surface-water quality. At intensive sites, also determine concentration and timing of pesticides in streams in watersheds dominated by suburban land use and cropland.	3 Basic	monthly, for 2.5 years	1-9, 11-16
		3 Intensive	same as above plus weekly-biweekly for 13 months	1-9, 11-16
Basinwide-synoptic studies— Tributaries with one predominant land use (37), large tributaries (19), and main-stem rivers (14)	Describe basinwide presence and distribution of nutrients and pesticides during primary periods of nutrient and pesticide applications to urban and agricultural lands. Use community-assemblage and habitat data as indicators of surface-water quality at basic and intensive tributary sites; and a subset of these ecological indicators at comparison watersheds with similar predominant land use and at tributary sites to Basic and Intensive Sites. Determine variability of water-quality and ecological indicators within and among watersheds having similar predominant land use. Compare indices among watersheds having different predominant land uses.	70 (includes Basic and Intensive Fixed Sites)	3 (June 1993, March 1994, May 1994)	1, (2), (3), (5)-(9), 11-13, (14), 15, (18)
Focused-synoptic studies (not differentiated on opposite page)	Poultry—(1) Evaluate nutrient concentrations and algal community assemblage data to understand eutrophication in watersheds predominated by poultry production. (2) Evaluate nutrients and turbidity under base-flow and stormflow conditions.	11	1 (May 1995)	4, 13, (14), 15
		31	2 (1992-93)	12, 13
	Suburban—Evaluate presence and distribution of nutrients and pesticides within Sope Creek watershed, the intensively monitored suburban watershed in Metropolitan Atlanta, with respect to differences in suburban land use. Also sampled three suburban watersheds larger than Sope Creek for comparison in May 1995.	14	3 (Aug 1994, Dec 1994, May 1995)	1, 12-16
	Metropolitan Atlanta and Columbus—Evaluate the presence and distribution of nutrients and pesticides across the land-use gradient from heavily urbanized to urbanizing watersheds. Twenty sites were within Peachtree Creek.	41	1 (July-August 1995)	1, (11), 12-16
	Tropical Storm Alberto—Determine concentrations in tributaries to the Flint River, and the Flint and Apalachicola Rivers during 100- to 500-year flood. Determine nutrient and pesticide loads near the mouth of the Flint River. Evaluate post-flood effects on fish communities in Lime Creek.	10	1-20 (July 4-27, 1994)	1, (2), (6), (7), (10), 11-16, (17)
Trace-element and organic-compound occurrence and distribution survey—Bed sediment and tissue	Determine the recent (at the time of sampling) occurrence and distribution of potentially toxic compounds in depositional zones of tributaries, main-stem rivers, and reservoirs. Streambed and reservoir sediments were analyzed for trace elements and hydrophobic organic compounds; and where available, aquatic-organism tissues (Asiatic clam, <i>Corbicula</i> , or mosquito fish, <i>Gambusia</i>) were analyzed for trace elements and lipophilic organic compounds.	48	1 or 2 (1992-94)	1, 6, 7, (8), (9), 13
Reservoir core study	Determine the historical (from the filling of each reservoir through 1994) occurrence and distribution of major ions, trace elements, and organochlorine compounds in depositional zones in six major reservoirs.	8 cores, 23 soil samples	1 or 2 (1994)	7
Land-use effects on ground-water quality				
Land-use studies	Agricultural—(1) Describe shallow water quality beneath cropland in the most intensively farmed part of the ACF River Basin (includes four forested areas as reference sites). (2) Limited study of nutrients beneath poultry and pasture land use (Peck and Garrett, 1994).	4 forest, 37 cropland wells	2 (1993, 1994)	12-17, 19, (20), (21), 23
		24 wells	1 (March 1993)	13
	Suburban and urban—Describe shallow water quality beneath suburban and urban land use. Compare ground-water and surface-water quality in the Metropolitan Atlanta part of the Chattahoochee River watershed.	21 wells, 19 springs	1 (1994-95)	12-19, (21), 23
Study-unit survey	Describe water quality in the Upper Floridan aquifer, a principal source of irrigation and drinking water in the Coastal Plain.	26 wells, 15 springs	1 (1995)	12-21, 23
Flow-system study	Evaluate the fate of agricultural chemicals through the shallow ground-water flow system that underlies cropland and the adjacent forested flood plain, to areas of discharge in ditches, springs, and streams.	32 wells, 3 springs, 3 drains	1-6 (1993-97)	12-16, (17), (20)-(22), 23

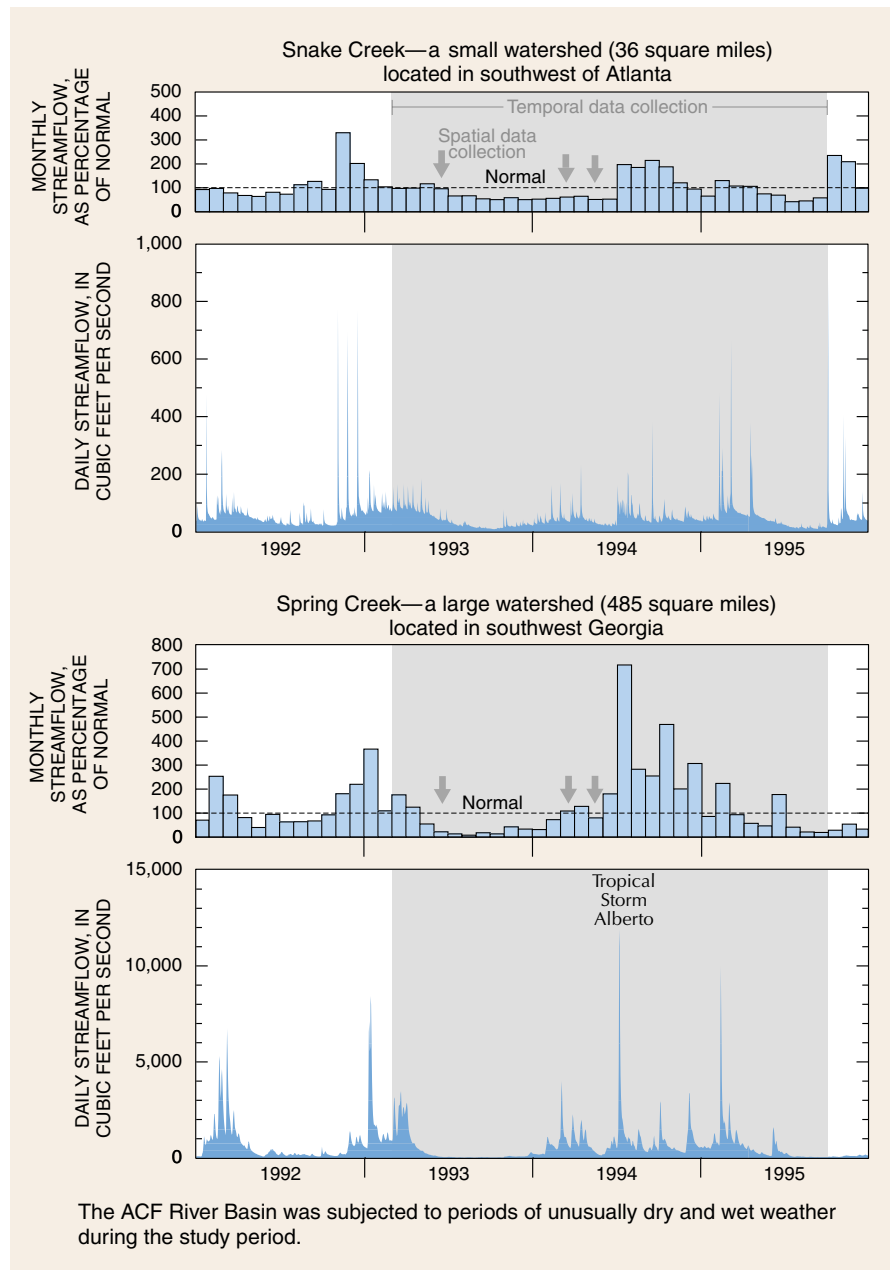
^{1/} 1, streamflow; **Community assemblage survey:** 2, fish; 3, macroinvertebrates; 4, algae; 5, habitat; **Bed sediment and reservoir cores:** 6, semivolatile organic compounds (SVOCs); 7, organochlorine compounds and polychlorinated biphenyls (PCBs), major ions, and trace elements (TE); **Tissue:** 8, SVOCs, organochlorine compounds, and PCBs; 9, major ions and TE; 10, bed material; **Water column:** 11, suspended sediment; 12, turbidity; 13, field parameters and nutrients; 14, major ions; 15, organic carbon; 16, pesticides; 17, volatile organic compounds (VOCs); 18, TE; 19, radon; 20, oxygen 18/16 ratio, hydrogen 2/1 ratio; **Age dating:** 21, tritium; 22, chlorofluorocarbons (CFCs); 23, water levels; constituents sampled at small subset of 'Number of sites' are in parentheses.

HYDROLOGIC CONDITIONS

The ACF River Basin has a warm, humid, temperate climate. Average annual precipitation ranges from 45 to 60 inches. During the period of intensive data collection (1993–95), average annual precipitation ranged from about 85 to 155 percent of normal. An extended period of dry weather from the summer of 1993 through the winter of 1994 resulted in below normal streamflows throughout much of the watershed. In contrast, rainfall from Tropical Storm Alberto caused extreme flooding in July 1994—primarily in the Flint River Basin.

Unusual hydrologic conditions such as droughts or floods may cause substantial changes in stream and ground-water quality and in aquatic communities. Although the water quality associated with these conditions may be of great interest, the short-term changes in water quality caused by droughts or floods can alter or mask the effects on water quality from other human and environmental factors being studied.

Stable streamflow conditions existed during spatial surveys, shown by arrows (three basinwide synoptic surveys and bed sediment and tissue surveys, pages 6 and 7), so that differences in water quality among sampled sites relate to human and environmental factors. However, the extended period of dry weather coincided with the data-collection period to evaluate temporal changes in water quality at stream locations representing various land uses (Basic and Intensive Fixed Sites, pages 6 and 7). The temporal data-collection period is shown by shading on the adjacent graph. Aycocks Creek, located in an area of cropland underlain by karst bedrock, ceased to flow for 6 months from June to December 1993, thus limiting comparisons among Aycocks Creek and other sites.



Dry weather from the summer of 1993 through the winter of 1994 caused many streams, such as Aycocks Creek—a tributary to Spring Creek (hydrograph shown above)—to cease flowing.



Rainfall from Tropical Storm Alberto caused devastating floods in parts of the ACF River Basin. (Photograph of the Flint River at Newton, Georgia, is by Timothy W. Hale, USGS, July 1994.)

WATER-QUALITY CONDITIONS DURING FLOODING CAUSED BY TROPICAL STORM ALBERTO, JULY 1994

In July 1994, rainfall from Tropical Storm Alberto caused devastating flooding over a large part of the ACF River Basin. Streamflows exceeded a 100-year recurrence interval throughout much of the Flint River Basin and exceeded a 500-year recurrence interval for more than 75 miles of the Flint River from Montezuma to Albany, Georgia (Stamey, 1995; 1996).



Cropland along Flint River near Oakfield, Georgia

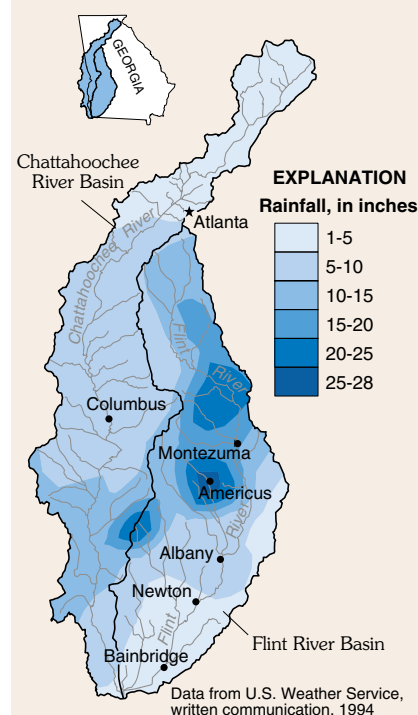


Flint River in Albany, Georgia

The slow rise and fall of floodwaters submerged some cropland and communities located near streams for up to a week (Photographs are by Timothy W. Hale, USGS, July 1994.)

directly attributed to fertilizer applications and wastewater discharges. The quantity of nitrogen and phosphorus in floodwaters of the Flint River represent just 4.5 and 2.8 percent, respectively, of estimated annual point and nonpoint sources of these nutrients from wastewater discharges, animal manure, and fertilizer in the affected area (Frick and others, 1996).

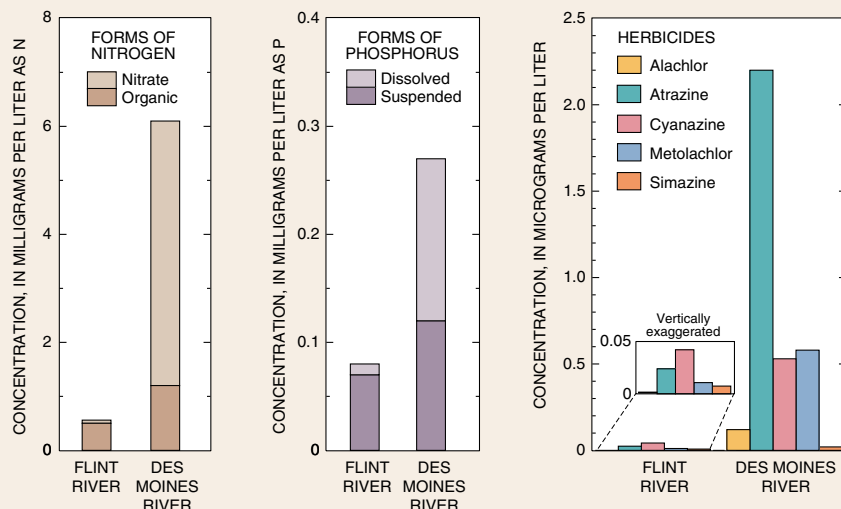
Pesticide concentrations in the Flint River peaked 4 to 6 days prior to the flood crest. Throughout the flood, pesticide concentrations in the Flint River and its tributaries were well below present USEPA drinking-water criteria (Nowell and Resek, 1994); only the insecticides carbaryl, diazinon, and chlorpyrifos approached or exceeded existing guidelines for protecting aquatic life. Herbicides used for selective preemergence weed control for cotton, corn, and peanuts were detected at higher concentrations than pesticides registered for other uses. However, the quantities present in floodwaters represented just 0.09 to 2.4 percent of the estimated annual use of these compounds on cropland within the affected area (Hippe and Garrett, 1995).



For much of the Flint River Basin upstream of Albany, Georgia, 10 or more inches of rain fell during Tropical Storm Alberto (July 4–7, 1994). The worst flooding in the Basin occurred between Atlanta and Newton, Georgia.

Floodwaters caused dam breaks; damaged roads, culverts, and bridges; and inundated several communities and large areas of prime agricultural land. Although nutrients and pesticides were present in floodwaters, the large volume of runoff and redeposition of sediment and associated contaminants in flood plains may have greatly reduced concentrations and downstream transport in floodwaters.

Nitrogen and phosphorus concentrations during flooding were similar to long-term average concentrations observed at monitoring sites in the Flint River Basin. The predominant forms of nitrogen and phosphorus in floodwaters are associated with transported organic detritus and fine-grained sediments eroded from upland areas, rather than forms that can be



Nutrient and pesticide concentrations were substantially lower during flooding of the Flint River following Tropical Storm Alberto in July 1994, than during flooding of tributary streams in the Upper Mississippi River Basin in July 1993 (Emitt C. Witt, II, USGS, written communication, 1994). Less intensive crop production and more extensive buffering of stream sides by forests and wetlands may have contributed to lower nutrient and pesticide concentrations in floodwaters in the Flint River.

MAJOR ISSUES AND FINDINGS

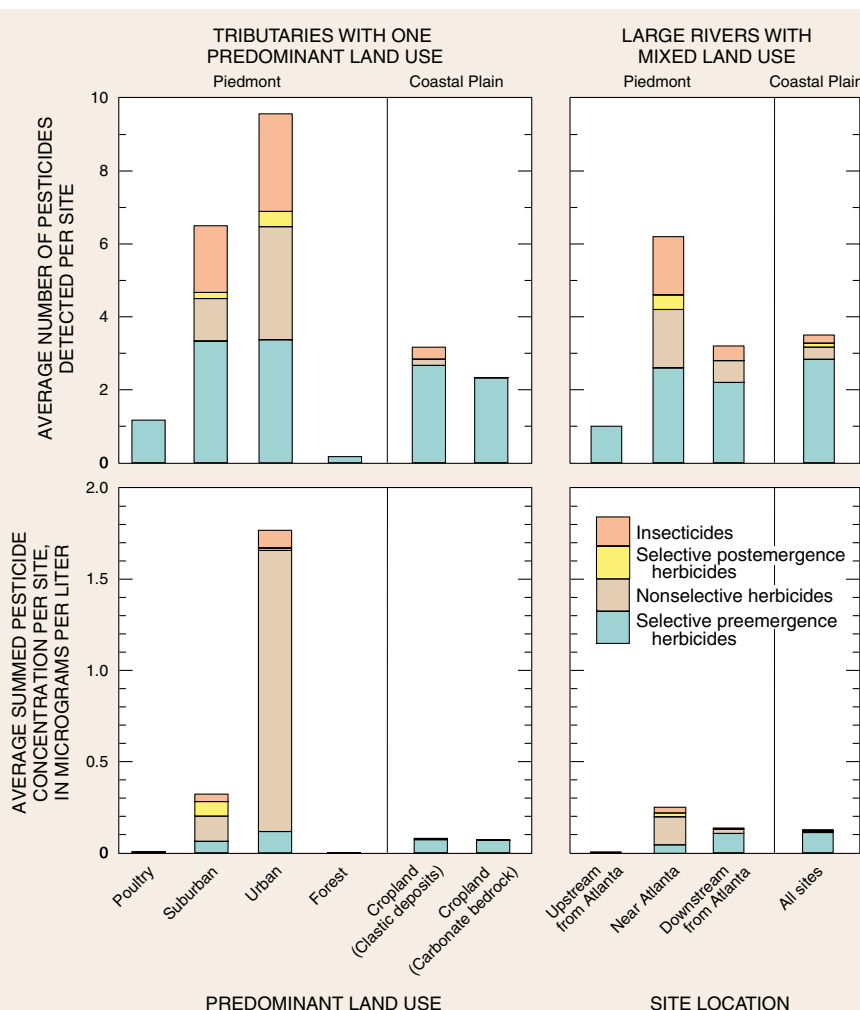
Pesticides in Streams

The land-use-based design of the ACF River Basin NAWQA study and use of highly sensitive analytical methods have provided an improved understanding of the occurrence and distribution of a broad range of pesticides in streams and selected aquifers in the ACF River Basin. Spatial and temporal patterns of pesticide occurrence in streams and ground water are described and associated in part with land use and pesticide use. The pesticides used have a broad range of chemical and physical properties that also control their temporal and spatial occurrence in the basin.

Pesticides are used to control weeds, insects, and plant diseases in each of the major land-use areas of the ACF River Basin (Stell and others, 1995). An estimated 17 million pounds of 147 different pesticide active ingredients are applied annually to agricultural land in the 20,000-square-mile study area (Anderson and Gianessi, 1995). Unlike much of the Nation, pesticides are applied throughout much of the year in the ACF River Basin and include similar quantities of herbicides, insecticides, fungicides, soil fumigants, and harvest aids.



Pesticides are widely used to control weeds, insects, and plant diseases in the ACF River Basin.



Herbicides that provide selective preemergence weed control are widely used in the ACF River Basin; they are the predominant type of pesticide detected in streams draining forested and agricultural areas. Streams draining suburban and urban areas, and large rivers located near and downstream from urban areas contain a more diverse mixture and higher concentrations of pesticides than other areas of the ACF River Basin, and includes compounds that are used for insect control and selective preemergence and postemergence weed control and nonselective weed control.

In the ACF River Basin, spatial surveys (results shown above) indicate that pesticides are most prevalent in streams draining areas of suburban and urban land use. Streams in these areas contain compounds used to control a broad range of pests, including: herbicides used for selective preemergence and postemergence weed control on turf; herbicides used for nonselective control of weeds, shrubs, and trees in transportation and utility right-of-way; and insecticides used to control pests in gardens, grass, ornamental shrubs, trees, and structures. In streams draining

agricultural areas, herbicides used for selective preemergence weed control predominate, despite the extensive use of other types of pesticides. The spatial data indicate that the continued urbanization of forested and pasture land surrounding Metropolitan Atlanta (page 4) are likely to be accompanied by increasing numbers and concentrations of pesticides in area streams, including the area's source of drinking water.

Pesticide concentrations in stream-water samples from all major land uses in the ACF River Basin were less than

USEPA standards and guidelines for lifetime exposure in drinking water (Nowell and Resek, 1994). However, concentrations of one or more insecticides in streams draining areas of suburban and urban land use often exceeded existing chronic exposure criteria for protection of freshwater aquatic life. Insecticides are but one of several potential chemical and physical stressors that exist in these streams.

The highest measured concentrations of most pesticides coincided with the growing season, from March through October, when many of these compounds are used. However, the highest measured concentrations of several herbicides used for selective preemergence weed control in suburban and urban areas peaked during the winter months—these compounds are applied to lawns during fall and winter months to control winter weeds. Winter applications of selective pre-

emergence herbicides on turf coincide with periods of high base flow and frequent stormflows and may contribute to higher concentrations and quantities of these pesticides in streams relative to other pesticides applied during the growing season.

Some pesticides persisted in streams within the ACF River Basin well beyond their normal application periods. These compounds include some selective preemergence herbicides, nonselective herbicides, and insecticides used on suburban and urban land; and some selective preemergence herbicides used on agricultural land. Insecticides commonly were present throughout the year in streams draining areas of suburban and urban land use, and in large streams that receive runoff from urban areas. Concentrations of one or more of these insecticides (primarily diazinon, carbaryl, chlorpyrifos, and malathion) exceeded existing guidelines for

protection of aquatic life throughout the year in streams draining these areas (Hippe and others, 1995).

Most pesticides present in streams draining major land uses in the ACF River Basin have chemical and soil properties that cause them to have a greater potential to run off than other less frequently detected compounds. Pesticides used for selective preemergence weed control and nonselective weed control, in particular, are rather water soluble and persist in soils following applications to provide seasonal or longer term weed control—these properties also increase their potential to run off to streams relative to other compounds. Herbicides that are used for nonselective weed control are applied at up to 10 times the rate of similar compounds used for selective weed control—these higher rates also may increase their potential to be present in nearby streams.

**Sope Creek—a predominantly suburban watershed
(29 square miles) in Metropolitan Atlanta**

Compound detected*	Frequency of detection, in percent	Maximum concentration (µg/L)	January	February	March	April	May	June	July	August	September	October	November	December
Selective preemergence herbicides														
Atrazine	96	.38												
Benfluralin	14	.022												
Metolachlor	15	.068												
Pendimethalin	42	.24												
Pronamide	10	.021												
Simazine	94	8.2												
Trifluralin	15	.019												
Selective postemergence herbicides														
MCPA	19	.42												
2,4-D	20	.63												
Nonselective herbicides			(no particular application period)											
Prometon	59	.86												
Tebuthiuron	68	.16												
Insecticides														
Carbaryl	63	.24												
Chlorpyrifos	61	.051												
Diazinon	92	.45												
Malathion	14	.14												

*Additional pesticides that were less frequently detected (less than 10 percent of 71 samples analyzed): DCPA, deethylatrazine, napropamide, oryzalin, propanil, trichlopyr, 2,4-DB, bromacil, diuron, terbacil, p,p-DDE, ethoprop, lindane, parathion, propoxur




**Lime Creek—a predominantly cropland watershed
(62 square miles) in southwest Georgia**

Compound detected*	Frequency of detection, in percent	Maximum concentration (µg/L)	January	February	March	April	May	June	July	August	September	October	November	December
Selective preemergence herbicides														
Alachlor	21	0.011												
Atrazine	64	0.21												
Cyanazine	12	0.77												
Deethylatrazine	25	.007												
Fluometuron	21	1.6												
Metolachlor	66	0.34												
Norflurazon	14	1.4												
Simazine	47	0.16												
Trifluralin	21	0.20												
Nonselective herbicide			(no particular application period)											
Tebuthiuron	23	0.050												
Insecticide														
Fonofos	10	1.2												

*Additional pesticides that were less frequently detected (less than 10 percent of 73 samples analyzed): benfluralin, bentazon, butylate, ethylfluralin, metribuzin, pendimethalin, 2,4-D, p,p-DDE, malathion, ethoprop, carbaryl, and chlorothalonil

EXPLANATION

Month when pesticide:

 Application is recommended	 Was detected	 Detected at highest concentration
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Maximum measured concentrations of most pesticides coincided with application periods to turf in the suburban watershed and to peanuts, cotton, and corn in the watershed dominated by cropland. Pesticide concentrations generally decreased to less than detectable levels during other parts of the year. However, several compounds persisted throughout the year in the suburban watershed.

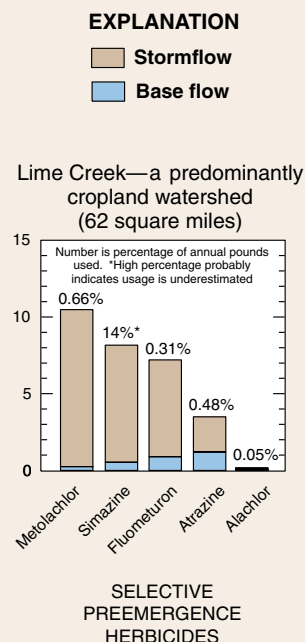
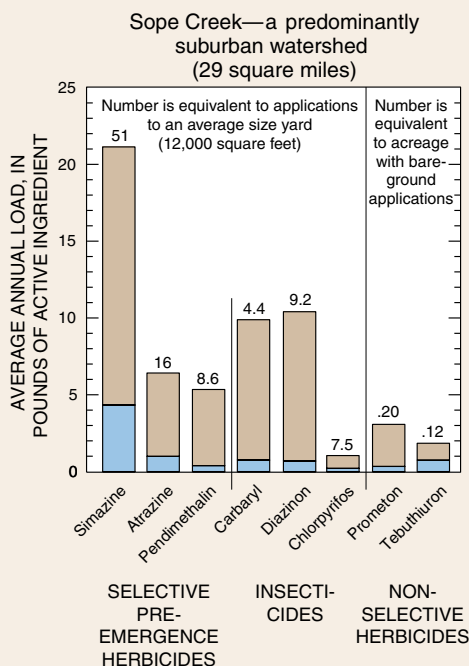
MAJOR ISSUES AND FINDINGS

Pesticides in Streams

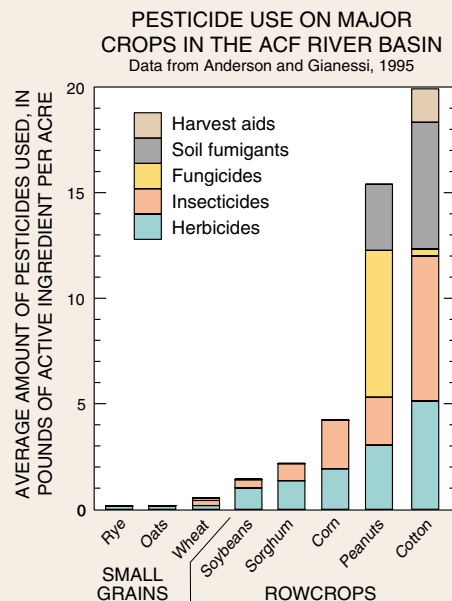
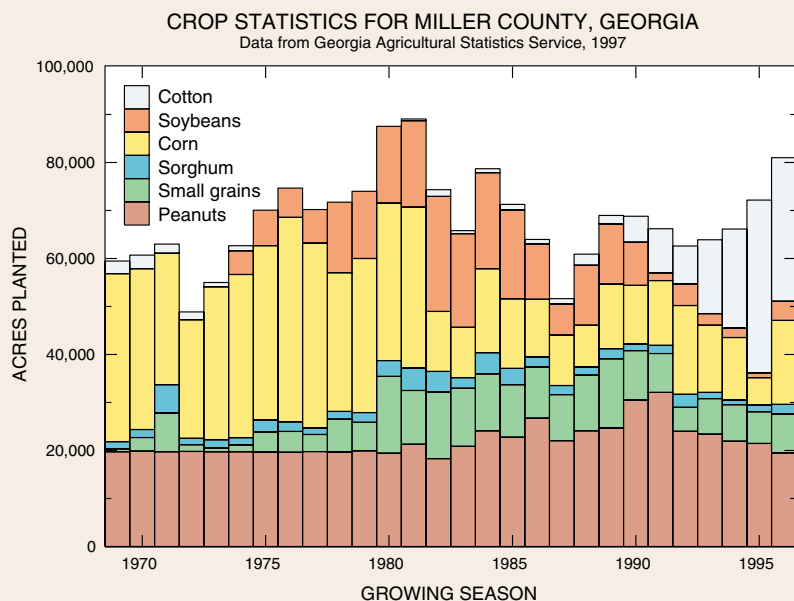
Stormflows transport from 60 to 90 percent of the total quantity of pesticides carried by streams draining urban and agricultural land in the ACF River Basin. Large storms that coincide with pesticide application periods in particular transport much of the annual pesticide loads in streams within the basin.



Several minor crops are grown in the ACF River Basin including pecans (shown above), peaches, melons, cucumbers, squash, tomatoes, snap beans, sweet peppers, and collard greens. About 3.2 million pounds of pesticides are used annually on these crops (Anderson and Gianessi, 1995). (Photograph is by Debbie Warner, USGS.)



Storm runoff carries much of the pesticides transported by streams draining cropland and suburban land. The quantities of pesticides transported are low relative to the quantities applied because pesticides are primarily retained in the soil and degraded or are transported from these watersheds by other pathways.



In the ACF River Basin, plantings of cash crops vary from year to year in response to changing weather and market conditions. From 1992 to 1995, cotton plantings increased by over 400 percent in many counties, in response to increasing demand for cotton lint and improved cotton yields resulting from eradication of the boll weevil. Because cotton acreage generally uses more pesticides than the corn and soybean acreage it displaced, the recent changes in crop patterns have caused a substantial increase in the quantity and number of pesticides applied to cropland in the basin.

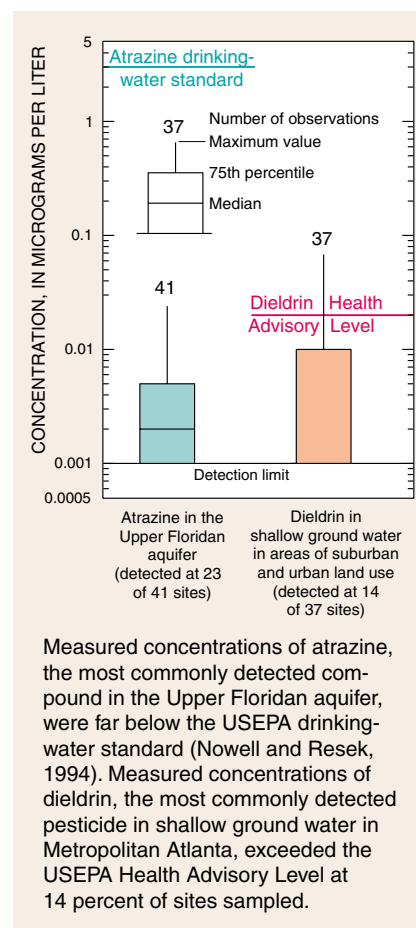
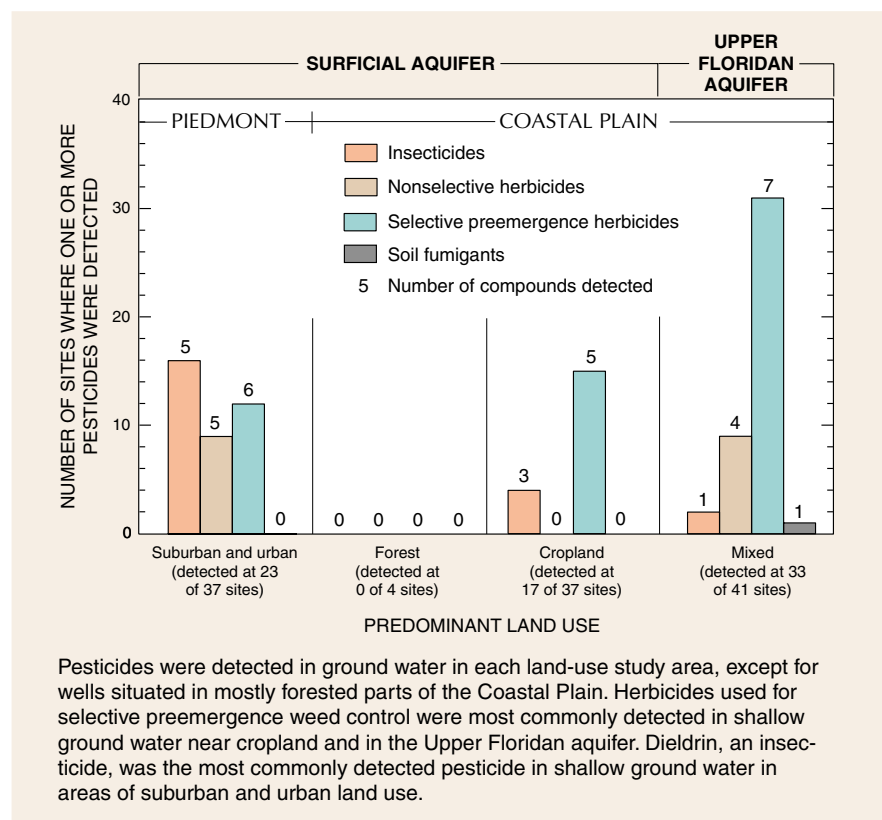
From 8 to 16 pesticides were detected in water samples collected from each of the three ground-water study areas (Frick and Crandall, 1995; Frick, 1997; Hippe, 1997). Pesticides were detected with least frequency in water from surficial aquifers sampled adjacent to cropland and most frequently in samples from springs and wells located in the recharge area of the Upper Floridan aquifer, a karst aquifer that is susceptible to contamination from bacteria and agricultural chemicals.

Pesticide concentrations in ground-water samples generally were less than current human health criteria for drinking-water safety. However, dieldrin concentrations in water samples collected during 1994–95 from 5 of 37 sites in Metropolitan Atlanta exceeded the USEPA Health Advisory Level. Dieldrin had been used on agricultural land prior to 1975 and for structural termite control until 1987 (Buell and Couch, 1995). The presence of dieldrin in ground-water

samples collected several years after being banned is indicative of the compound's persistence in soils and ground water.

Ground-water samples collected from the recharge area of the Upper Floridan aquifer and from surficial aquifers located in areas of suburban and urban land use contained a broader variety of pesticides than samples collected from shallow ground water adjacent to cropland. Pesticides detected in these study areas include insecticides used for structural and turf insect control and herbicides used for selective preemergence and nonselective weed control. Herbicides used for selective preemergence weed control are the predominant type of pesticide present in ground-water samples from wells adjacent to cropland. Pesticides detected in ground-water samples generally have a larger potential to leach into ground water than many other currently used pesticides that were not detected.

Several of the pesticides detected in ground-water samples are now banned from use (dieldrin and 1,2-dichloropropane) or were in much greater use a decade or more prior to the sampling period (page 12). Atrazine and alachlor were commonly detected in surficial aquifers adjacent to cropland and the Upper Floridan aquifer, but probably were in greater use in the 1970's and 1980's (prior to the resurgence of cotton) when corn and soybeans were a large percentage of the planted acreage. Ground water and associated contaminants commonly are in the subsurface for years or decades between the time they enter the aquifers and the time they discharge to springs and streams. Because of the long residence time, the occurrence of pesticides in ground water from wells often lag any changes in pesticide-use patterns by years or occasionally decades.



MAJOR ISSUES AND FINDINGS

Nutrients and Suspended Sediment in Streams

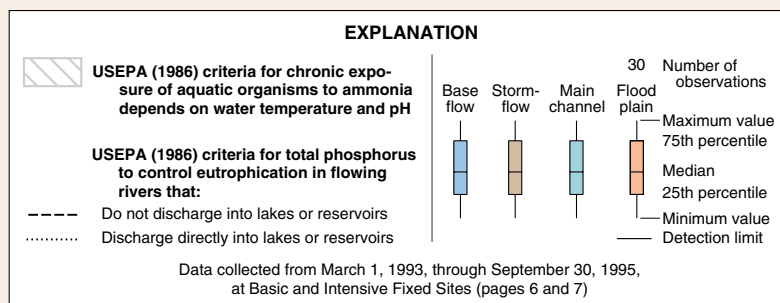
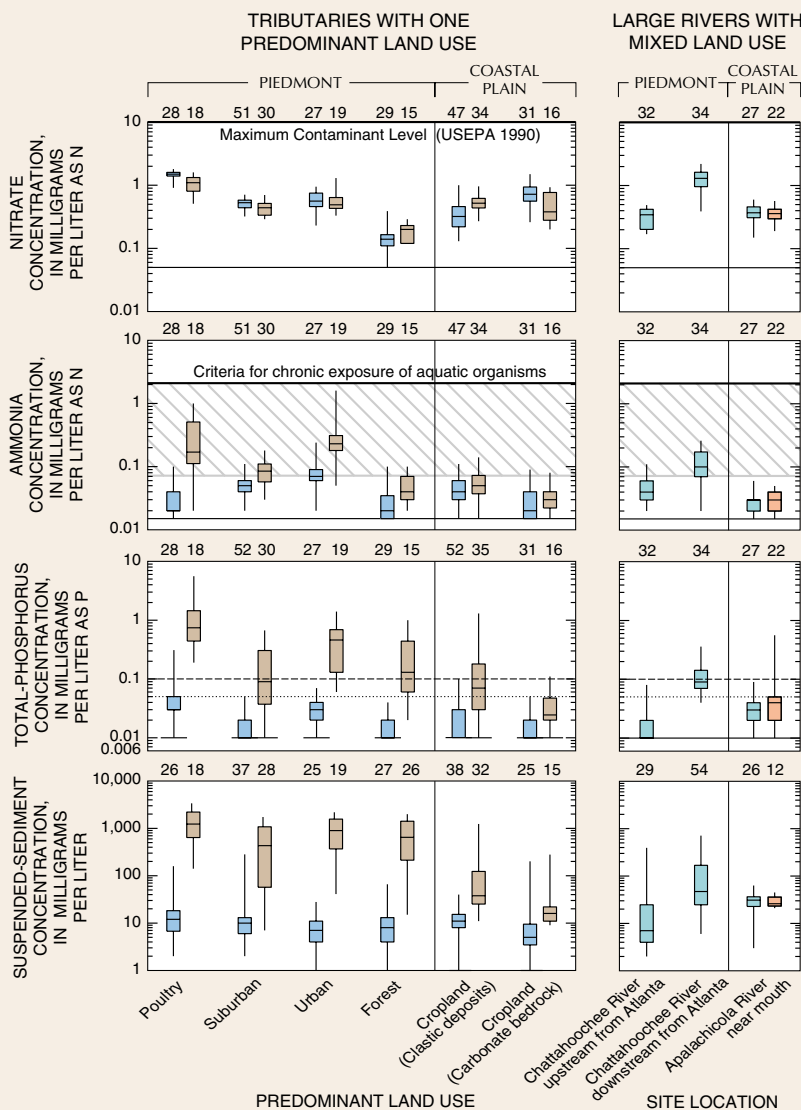
The land-use based design of the ACF River Basin NAWQA study provides an improved understanding of nutrient and suspended-sediment concentrations and yields in streams in the ACF River Basin. Differences in nutrient concentrations and yields among predominant land-use settings provide preliminary guidance for water-resource managers to focus efforts to control nutrients and suspended sediment in varying land-use settings.

Analysis of data for the years 1972 to 1990 from stream-water-quality monitoring networks provided a good understanding of the occurrence and distribution of nutrients in main-stem rivers and, to a lesser extent, in reservoirs and large tributaries (Frick and others, 1996). However, because these networks focused on regulatory compliance upstream from drinking-water-supply intakes and downstream from wastewater-treatment plant outfalls, some monitoring sites were affected by point sources that tend to mask land-use effects on water quality.

Nitrogen and phosphorus are essential nutrients for plant life but when present in water at high concentrations they accelerate eutrophication of rivers and lakes. High concentrations of ammonia are toxic to aquatic life, and high concentrations of nitrate, primarily in ground water, are toxic to humans and other animals.

Sources of nutrients in the ACF River Basin include:

- Point sources: municipal and industrial wastewater effluent, and sanitary and combined sewer overflows.
- Nonpoint sources: animal manure, primarily chicken litter; fertilizer; runoff from agricultural, urban, and suburban areas; septic systems; atmospheric deposition; and decomposition of organic matter.

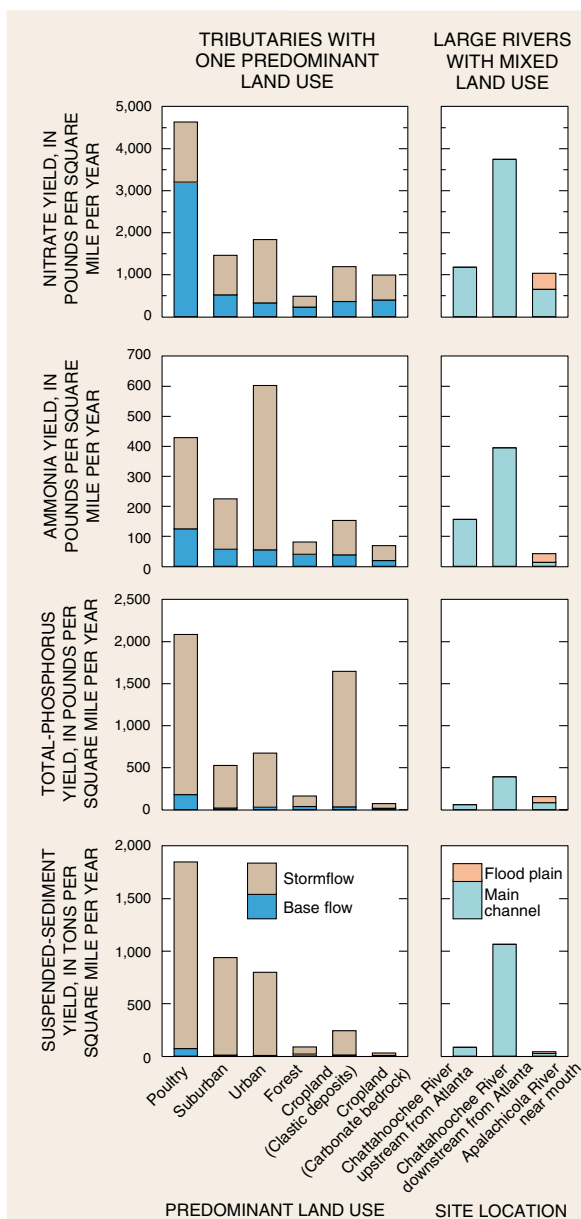


Concentrations during stormflows were significantly higher than during base flows for total phosphorus and suspended sediment at all tributary sites and for ammonia at poultry, suburban, and urban sites. Nitrate concentrations were highest in base-flow samples at the poultry site, indicating relatively high nitrate concentrations in ground water (page 17) that discharges to streams. Nutrient and suspended-sediment concentrations were significantly higher in the Chattahoochee River downstream than upstream from Atlanta. USEPA criteria for total phosphorus was most often exceeded during stormflow conditions at the poultry, urban, and suburban sites, and in the Chattahoochee River downstream from Atlanta. No ACF River Basin samples exceeded the ammonia criteria.

Since the early 1970's, substantial progress has been made toward reducing point sources of nutrients throughout much of the ACF River Basin (Frick and others, 1996). However, there are limited historical water-quality data from tributary streams to estimate nonpoint-source inputs of nutrients from individual land uses.

In streams, nutrient and suspended-sediment concentrations (page 14) and yields (page 15) are highly dependent on inputs from point and nonpoint sources, land-disturbing activities, and basin hydrology. The six Fixed Sites representing one predominant land use have no treated-wastewater outfalls upstream; however, there are two combined sewer overflows upstream from the urban site. During the study period, stormflow accounted for as low as 36 percent of annual volume of water at the poultry site, to as high as 82 percent at the urban site. Daily water releases from Lake Sidney Lanier account for much of the streamflow in the Chattahoochee River; therefore, streamflows were not separated into base flow and stormflow at sites upstream and downstream from Atlanta. Near the mouth of the Apalachicola River, approximately 40 percent of the flow is in the flood plain during high river stages.

The Basic Fixed Site at which poultry production was the predominant land use within the watershed had the highest concentrations and yields of nitrate, total phosphorus, and suspended sediment and the second highest concentrations and yield of ammonia of all Fixed Sites in the ACF River Basin. The primary nutrient source within this watershed and in most of the Chattahoochee River Basin upstream



Yields are calculated by dividing the amount of a compound flowing out of a watershed by the drainage area to facilitate comparisons among watersheds of different sizes. Within the ACF River Basin, highest nitrate yields are primarily the result of elevated nitrate concentrations in ground water in the watershed characterized by poultry land use and wastewater effluent in the Chattahoochee River downstream from Atlanta. Highest ammonia yields are associated with discharges of untreated wastewater upstream from the urban site, high ammonia concentrations during stormflow upstream from the poultry site, and wastewater in the Chattahoochee River downstream from Atlanta. Highest total-phosphorus yields are primarily the result of total-phosphorus concentrations during stormflow at the poultry site, and phosphorus associated with organic detritus, rather than as forms that can be directly linked to fertilizer applications, at the cropland site (watershed underlain by clastic deposits).

Data collected from March 1, 1993, through September 30, 1995, at Basic and Intensive Fixed Sites (pages 6 and 7). Load estimates based on computer program by Charles Crawford (USGS, written communication, 1998)

from Lake Sidney Lanier is poultry litter applied as fertilizer to pasture land (Frick and others, 1996). The base-flow component of nitrate yield at the poultry site is the only nutrient or suspended-sediment base-flow component that accounts for more than 50 percent of the annual yield. Water recharging shallow ground water in the area is enriched in nitrate primarily from poultry litter, which in turn enriches nitrate concentrations in ground water, the source of most base flow. In contrast to other nutrients and suspended sediment in various land-use settings, reducing nitrate yields in streams in watersheds characterized by poultry land use will involve reducing nitrate concentrations in ground water in addition to reducing concentrations in runoff during stormflow.

The predominantly urban and suburban sites and the Chattahoochee River downstream from Atlanta have relatively high nutrient concentrations and yields. Nutrient concentrations and yields at the suburban site are similar but slightly lower than at the urban site, with two exceptions. The first is that ammonia concentrations and yield are significantly lower at the suburban site because there are no combined sewer overflows. The second is that, although suspended-sediment concentrations are slightly lower at the suburban site, yield is slightly higher, probably as a result of more construction and development throughout the predominantly suburban watershed or construction at the sampling site, or both. High nitrate concentrations and yield in the Chattahoochee River downstream from Atlanta are primarily the result of nitrogen in wastewater effluent.

MAJOR ISSUES AND FINDINGS

Nutrients and Suspended Sediment in Streams

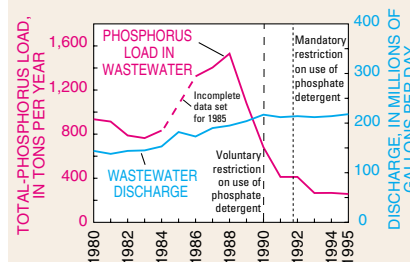
Low nutrient concentrations and yields at the forested and cropland sites, the Chattahoochee River upstream from Atlanta, and the Apalachicola River near its mouth are indicative of good water quality. Suspended-sediment concentrations at the forested site are similar to those at the urban site; however, the annual yield at the forested site is much lower because only 47 percent of the annual runoff

occurs during stormflow compared with 82 percent of the annual runoff at the urban site. A large number of reservoirs upstream, relatively slow stream velocities, intact riparian vegetation in wide flood plains, long travel times from upstream nutrient and suspended-sediment sources, and low population densities all contribute to the good water quality near the mouth of the Apalachicola River.

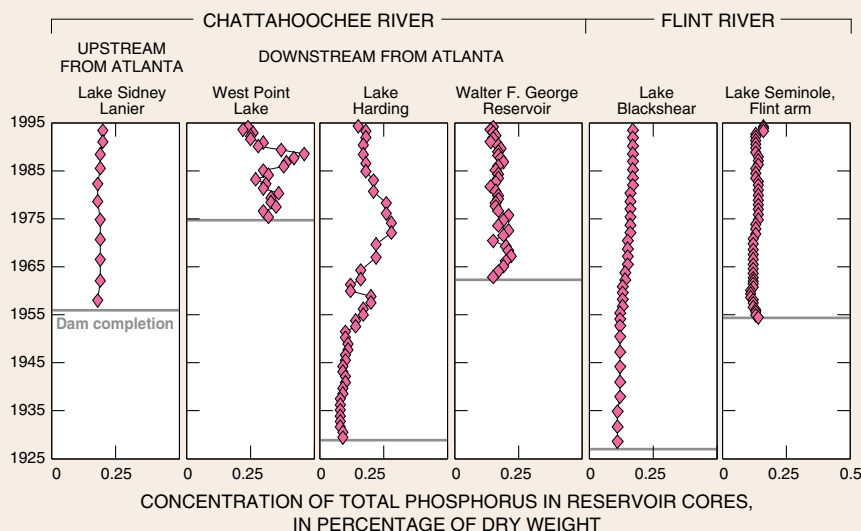
High nutrient and suspended-sediment yields from stormflows are indicative of primarily nonpoint sources of these constituents. Thus, more extensive control of stormwater runoff from poultry production, suburban, and urban areas would be needed to significantly reduce eutrophication of lakes and reservoirs in the ACF River Basin.

PREDOMINANT LAND USE, IN TRIBUTARIES	ANNUAL RUNOFF	ANNUAL YIELD				EXPLANATION Percentage transported during stormflow conditions
		Nitrate	Ammonia	Total phosphorus	Suspended sediment	
Poultry						
Suburban						
Urban						
Forest						
Agriculture (clastic)						
Agriculture (karst)						

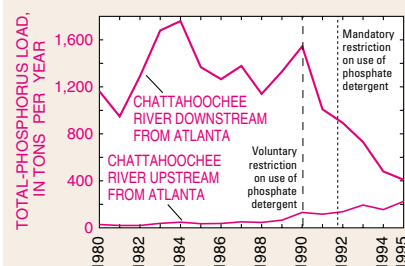
At tributary sites studied with one predominant land use, more than 60 percent of most nutrient yields occurs during stormflows. At the urban site, which has the highest percentage of impervious area in its watershed, more than 80 percent of runoff and nutrient and suspended-sediment yields occur during stormflows. The predominance of stormflow transport is indicative of primarily nonpoint sources of nutrients and suspended sediment.



Wastewater discharge to the Chattahoochee River from the six largest Metropolitan Atlanta wastewater-treatment facilities increased by about 50 percent from 1980 to 1995; however, the total-phosphorus load from these facilities decreased by about 83 percent from the largest load in 1988. Improved wastewater treatment accounts for about two-thirds of the decrease, and restrictions on phosphate detergents accounts for about one-third of the decrease (Hippe and others, 1997).



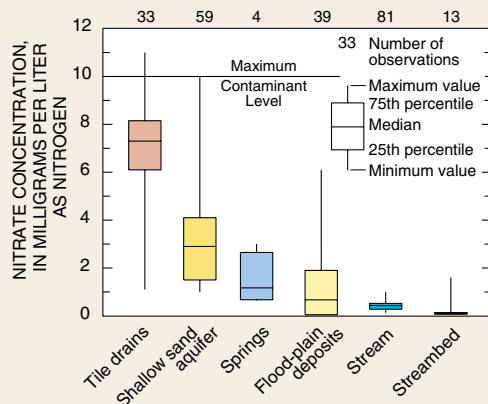
Although total-phosphorus concentrations of sediment deposited in reservoirs (page 21) throughout the ACF River Basin has increased slightly in the last half of the 20th century, the largest increases occurred downstream from Metropolitan Atlanta. Total-phosphorus concentrations of sediment in Lake Harding began declining after 1974 when West Point Lake was built upstream. Total-phosphorus concentrations in West Point Lake sediment increased until approximately 1988 when a relatively rapid decrease coincided with restrictions on (1) the use of phosphate detergents in Georgia, and (2) the concentration of phosphorus discharged by major wastewater-treatment facilities into the Chattahoochee River between Lake Sidney Lanier and West Point Lake.



Total-phosphorus loads in the Chattahoochee River downstream from Metropolitan Atlanta decreased by about 77 percent from the highest level in 1984 because of reductions in point-source loads. However, point sources continue to contribute a major part of the phosphorus load to the river. Between Lake Sidney Lanier and the upstream site shown in the above graph, there are no municipal or industrial discharges greater than 1 million gallons per day. Therefore, most of the increase in phosphorus loads in the Chattahoochee River upstream from Atlanta are from increasing nonpoint-source loads.

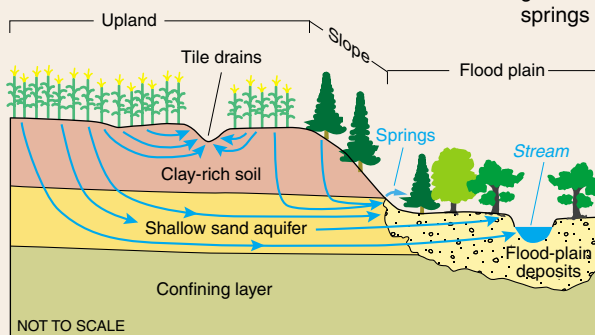
In some areas of the Nation, prolonged use of fertilizers or manure for crop production has led to high nitrate concentrations in shallow ground water that renders it unsafe for consumption by pregnant and nursing mothers, young infants, and young farm animals. In major crop-producing areas of the ACF River Basin, however, clay-rich upland soils and extensive forested flood-plain areas may reduce the risk of nitrate contamination of ground water and streams, respectively. A ground-water flow-system study site with these landscape and soil characteristics was studied to characterize (1) the spatial distribution of ground-water quality in relation to subsurface conditions and (2) the quality of water of the predominant ground-water discharge zones relative to that of the receiving stream.

Three distinctive subsurface environments were delineated on the basis of nitrate concentrations and other chemical indicators: (1) clay-rich soil, (2) shallow aquifer, and (3) flood plain deposits (see generalized cross section). In the farmed upland area, nitrate was



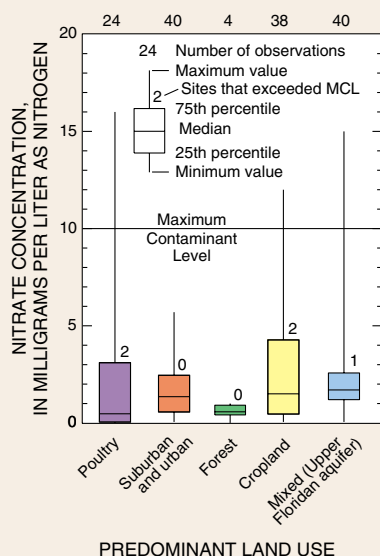
Upland soils in the Coastal Plain of the ACF River Basin commonly contain thick, continuous, clay layers. These clay layers impede the transport of agricultural chemicals to shallow and deeper aquifers.

Tile drains and ditch networks in farm fields are designed to drain areas where ground water is perched above clay layers. Runoff carried to streams by these drainage networks have higher concentrations of agricultural chemicals than (1) ground-water discharge from springs located along the edges of flood plains and (2) ground-water discharge to streams that first passes through organic-rich flood-plain deposits.



present in ground water both above and below clay-rich soil layers. However, tile drainage from above the restrictive soil layers has higher nitrate and lower dissolved-solids concentrations than water from wells screened in the shallow aquifer located below these soil layers. The clay-rich soil layers impede the downward flow of water, so agricultural chemicals that are applied to cropland tend to stay in shallow soil layers where they are used by crops or degraded. In water from wells screened in flood-plain deposits, nitrate was absent or present at significantly lower concentrations than in the upland areas. Organic-rich layers within flood-plain deposits rarely contained nitrate because nitrate is chemically unstable in the reducing conditions that characterize these layers.

the stream channel. Tile drains and ditches were sustained by a perennial discharge of ground water derived locally from the shallow subsurface overlying restrictive clay layers. Ground-water flow from the shallow aquifer sustains a line of springs as well as seepage through the streambed to the stream; however, seepage through the streambed only rarely contained detectable nitrate. Median nitrate concentrations of water samples analyzed from each discharge zone are 7.3, 1.2, and less than 0.05 milligrams per liter as nitrogen, respectively, or about 17, 2.7, and less than 0.10 times that of the median nitrate concentration of the receiving stream. Nitrate loadings from tile drains are very high relative to their discharge volumes, and where tile drains are present they represent an important pathway for transport of nitrate and other agricultural chemicals to streams during base-flow conditions (ground-water discharge) and during periods of storm runoff.



Although nitrate generally is present in ground water in each of the land-use settings and in the Upper Floridan aquifer, concentrations only rarely exceed the USEPA drinking-water standard of 10 milligrams per liter as nitrogen.

Three ground-water discharge zones also were delineated: (1) tile drains and ditches in upland draws, (2) a line of intermittent and perennial springs at the edge of the flood plain, and (3) seepage zones through the bed of

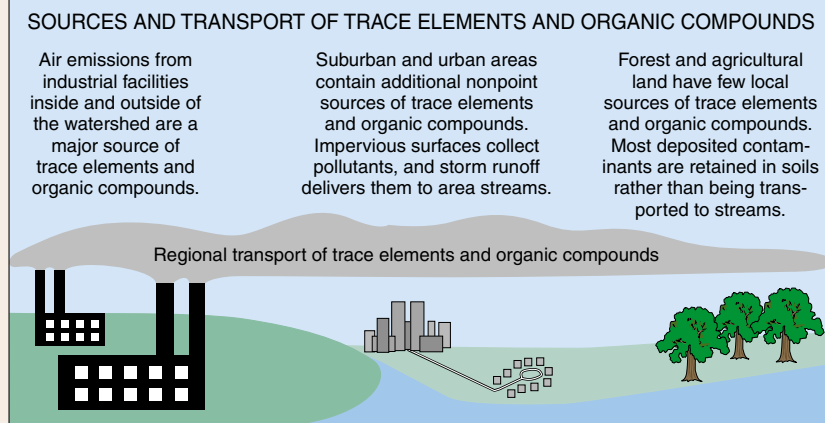
MAJOR ISSUES AND FINDINGS

Trace Elements and Organic Compounds in Bed Sediment

Spatial surveys of bed and bottom sediments in rivers, reservoirs, and wetlands of the ACF River Basin were performed (see maps on pages 26–27) to determine the extent of environmental contamination by trace elements (mostly heavy metals) and synthetic organic compounds. Samples from 48 sites were analyzed to compare contaminant concentrations in the recently deposited sediments of watersheds with different predominant land uses and hydrogeology. Contaminant concentrations also were compared to quantities of the contaminants released to the atmosphere from permitted facilities located within and around the Study Unit. Twenty-one sites are located on main-stem rivers or reservoirs, five sites are on large tributaries to the Flint River, and 22 sites are on streams draining smaller watersheds with a predominant land use.

The largest trace-element enrichment (summarized in illustration on page 19) was in (1) urban and suburban watersheds draining portions of Metropolitan Atlanta and Columbus, (2) main-stem and reservoir settings on the Chattahoochee River downstream from Atlanta, and (3) the Flint River downstream from Albany. Some exceptions to this pattern are evident, including: (1) copper enrichment throughout the Piedmont, (2) mercury and lead enrichment in small forested watersheds in the Coastal Plain, (3) mercury and copper enrichment in the Chattahoochee River upstream from Atlanta, and (4) cadmium and mercury enrichment in the large Coastal Plain tributaries to the Flint River.

Much of the transport and deposition of trace-element contaminants to receiving watersheds may occur along regional atmospheric pathways. However, urban landscapes with high percentages of impervious areas, such as industrial and transportation areas, enhance the movement of airborne trace elements to waterways.



Exposure to high concentrations of trace elements and organic compounds in aquatic sediments are a health risk both to the aquatic life and terrestrial animals (including people) that consume food resources taken from our waterways. Although soils and rocks contain low concentrations of most trace elements, much of the current pollutant load of these contaminants is derived from industrial emissions and urban nonpoint sources. The dominant pathways involve regional atmospheric transport and deposition on land. Urban land areas have high percentages of impervious surfaces that collect pollutants and storm drains that carry pollutants to nearby streams.

Facilities reporting releases of metals and organics to the atmosphere within 300 miles of Albany, Georgia, from 1987 to 1993. Data from: http://www.epa.gov/opptintr/tri											
Industry	TRACE ELEMENTS						ORGANICS			Total ¹ metals	Total ¹ organics
	As	Cd	Hg	Cu	Pb	Zn	PAHs	Phenols	Phthalates		
Food preparation	5	0	0	44	0	33	0	0	0	48	0
Textiles	0	0	0	3	4	9	24	2	11	12	36
Lumber and wood	65	0	0	65	0	0	20	18	3	69	31
Paper products	0	0	0	0	0	8	5	31	1	8	35
Chemicals	6	1	5	46	28	86	54	55	45	121	123
Petroleum and coal	0	0	0	4	3	9	7	2	0	11	9
Rubber and plastics	1	6	1	3	12	47	4	5	28	59	37
Stone, clay, glass	0	0	0	3	6	10	4	9	6	12	16
Metal products	6	11	0	109	95	93	21	28	4	185	40
Industrial machinery	0	0	0	11	6	5	1	2	2	16	5
Electronics	0	3	3	31	25	15	0	6	0	60	6
Transportation equipment	0	0	0	13	13	13	2	7	10	29	19
Total facilities	83	21	9	332	192	328	142	165	110	630	357
Total emission 1987-93, in thousands of pounds	48	11	41	1,200	960	4,900	4,500	4,400	1,600	7,200	10,500

¹ The totals may not equal the sum of the parts because a particular industry may emit more than one trace element or organic compound.

Toxic Release Inventory (TRI) release-to-air data for industrial facilities within 300 miles of Albany, Georgia, are summarized for the years 1987–93 for six toxic trace elements and three categories of organic compounds that are toxic, carcinogenic, or both. The 300-mile-radius airshed was conservatively chosen as a potential contributing area to the ACF River Basin. Releases to air of arsenic, cadmium, mercury, copper, lead, and zinc were reported for 630 facilities representing 12 industrial categories. Copper, lead, and zinc accounted for 99 percent of the total load of 7.2 million pounds during 1987–93, whereas arsenic, cadmium, and mercury accounted for only 1 percent of that load. Polycyclic aromatic hydrocarbons (PAHs), phenols, and phthalates accounted for the release of 10.5 million pounds of organic compounds by 357 facilities during 1987–93.

MAJOR ISSUES AND FINDINGS

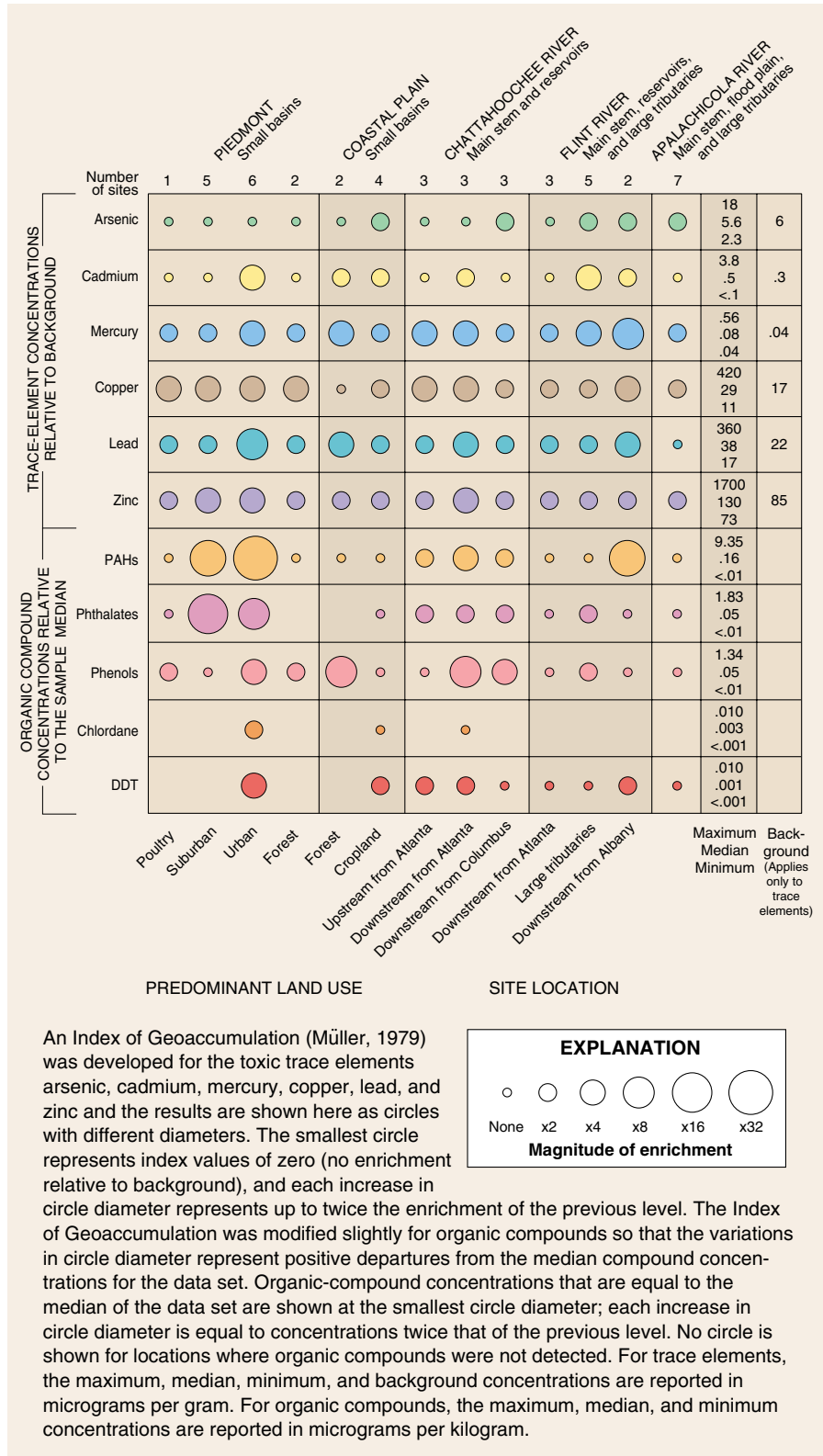
Trace Elements and Organic Compounds in Bed Sediment

Among organic compounds present in streambed sediments, polycyclic aromatic hydrocarbons (PAHs) and phthalates were at highest concentrations in (1) suburban and urban watersheds in Metropolitan Atlanta and Columbus, (2) main-stem reaches of the Chattahoochee River downstream from Atlanta and Columbus, and (3) the Flint River downstream from Albany. Unlike the trace elements that naturally occur at background concentrations in most soils and sediments, PAHs and phthalates are present in sediments as contaminants from industrial activity, fossil-fuel combustion, or waste incineration. PAHs are released from wood and other plant material by fires. Phthalates are used for production of plastics and plastic products. Phenols have many industrial and natural sources and are widely distributed in sediments of the ACF River Basin.



Bed-sediment samples are sieved and the silt and clay fractions are analyzed to minimize effects of grain size on patterns in trace-element chemistry.

Although most organochlorine insecticides such as chlordane and DDT have been banned from use, residual quantities of these compounds and their degradation products are common in the sediments of the ACF River Basin. Chlordane and DDT were at highest concentrations in urban watersheds of Atlanta and Columbus, but also were present in watersheds draining cropland and in main-stem and reservoir sites. Chlordane was used as an insecticide on cropland until the mid-1970's and for building and foundation pro-

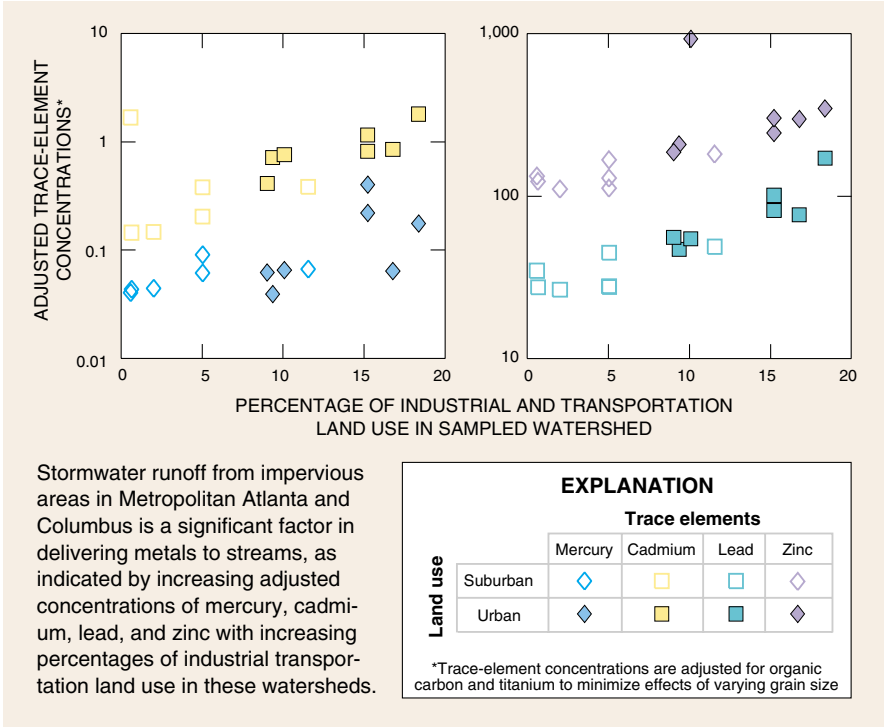


tection against termite damage until the late 1980's. DDT was used through

the early 1970's as an insecticide, both in agricultural and urban settings.

MAJOR ISSUES AND FINDINGS **Trace Elements and Organic Compounds in Bed Sediment**

Although much of the transport of airborne pollutants is regional, storm-water runoff from impervious areas is a major factor in increasing trace-element concentrations in receiving streams. Concentrations of mercury, cadmium, lead, and zinc in the stream-bed sediments of suburban and urban watersheds in Metropolitan Atlanta and Columbus increased in direct proportion to the percentage of industrial transportation land use in these watersheds. This direct response likely is the result of deposition of emissions from regional and local sources on impervious surfaces and subsequent transport of these pollutants in stormwater runoff to streams.



Stormwater runoff from impervious areas in Metropolitan Atlanta and Columbus is a significant factor in delivering metals to streams, as indicated by increasing adjusted concentrations of mercury, cadmium, lead, and zinc with increasing percentages of industrial transportation land use in these watersheds.



Wastewater-treatment plant



Coal-burning power plant



Litter and debris in an urban stream

Urban areas have additional local sources of trace elements and organic compounds. The USEPA Toxic Release Inventory (TRI) data base (<http://www.epa.gov/opptintr/tri>) contains annual emissions to air, land, and water of more than 600 toxic chemicals. Industries and Federal facilities that either manufacture more than 25,000 pounds of, or use more than 10,000 pounds of, any designated chemical per year are required to report their releases. Currently, reported releases to water are minimal and releases to land are to landfills or other secured areas with low potential for transport to waterways. Therefore, releases to air provide the best available estimate of trace-element and organic-compound inputs for regional assessments. However, smaller industrial producers and users of trace elements and organic compounds, wastewater-treatment plants, and coal- and oil-burning power plants do not contribute emissions information to the TRI data base. Also, the quantities of local inputs of trace elements and organic compounds from nonpoint sources, such as automobile emissions and litter and debris disposed along roadways and streams, are not known. (Photograph of power plant is by Steve Kandell, Atlanta Regional Commission.)

MAJOR ISSUES AND FINDINGS

Historical Trends in Water Quality Determined from Reservoir Cores

In 1994, six reservoirs located in the ACF River Basin were selected for sediment coring as part of a NAWQA pilot program designed to relate effects of land-use changes through time to historical water quality of the impounded watersheds. The reservoirs sampled are situated along the main stems of the Chattahoochee and Flint Rivers. Their watersheds have different predominant land uses and dates of dam completion. Thus, not only can the temporal history of the age-dated cores be related to historical land-use changes, but the effects of upstream impoundments on the sediment chemistry in older reservoirs located downstream can be used to infer the source areas for selected pollutants.

Reservoirs are efficient sediment traps. Sediments deposited in a reservoir retain a physical and chemical history of the effects of human activities on the reservoir watershed. Detailed analysis of sediment cores collected from reservoirs allow scientists to reconstruct historical trends in stream-water quality. When accompanied by historic patterns of urban growth, industrial activity, and agricultural land-use, the results of this synthesis provide an invaluable tool for long-term environmental assessment.

Sediment cores were collected and age-dated by methods described in Van Metre and others (1997) and analyzed for organochlorine compounds and trace elements. The years 1952 and 1963–64 were assigned to depths in sediment cores from the four older reservoirs on the basis of patterns in radioactive cesium (^{137}Cs) concentrations; higher concentrations correspond to past periods of above-ground hydrogen-bomb testing. Ages of dam completion were assigned to cores from all the reservoirs (except Lake Harding) by locating transitions between stream and reservoir sediments.

Six major reservoirs in the ACF River Basin were used to evaluate historical trends in water quality. **Lake Sidney Lanier**, which is on the Chattahoochee River about 45 miles upstream from Atlanta, was impounded by the U.S. Army Corps of Engineers (Corps) in 1956, primarily for flood control and hydropower generation. Although the predominant land uses are forest and pasture, much of the pasture land is used for the disposal of chicken litter. Urban growth in the Lake Sidney Lanier watershed has increased pollutant loads to the reservoir, as has extensive land clearing for subdivisions in rapidly developing suburban settings.

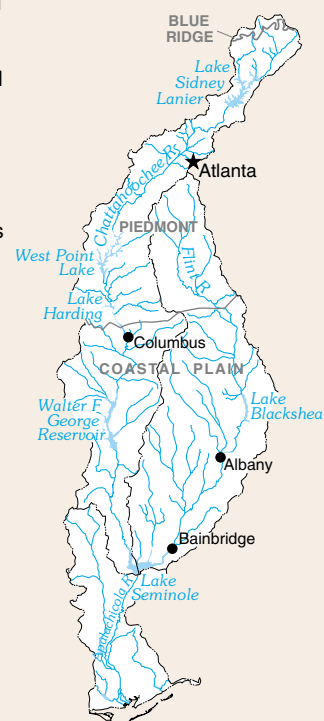
West Point Lake was constructed by the Corps in 1974 and is located approximately 60 miles downstream from Atlanta. Urban and suburban growth in the Metropolitan Atlanta area accelerated beginning in the late 1970's and has continued at a rapid pace to the present.

Lake Harding, on the Chattahoochee River downstream from Atlanta (105 miles) and upstream from Columbus (18 miles), is the oldest reservoir of the six ACF reservoirs studied. Georgia Power Company constructed the Lake Harding dam in 1926 for hydropower generation.

The Chattahoochee River is a navigable waterway from Columbus downstream to Lake Seminole. Part of this navigation channel includes **Walter F. George Reservoir**, located approximately 35 miles downstream from Columbus and constructed by the Corps in 1963 for flood control, hydropower generation, and navigation. Although the surrounding land largely is forested with some cropland and pasture, the urban influence of Columbus also affects the water quality and sediment chemistry of this reservoir.

Lake Blackshear, the first impoundment on the Flint River, is almost 200 miles downstream from the Flint River's headwaters at Atlanta's Hartsfield International Airport. This reservoir was filled in 1927 upon completion of Warwick Dam by the Crisp County Power Commission. Although the Flint River watershed begins in Atlanta, Lake Blackshear's water quality is little affected by urban land use. The Piedmont portion of the Lake Blackshear watershed largely is a patchwork of forest, cropland, and pasture; the Coastal Plain portion is predominantly cropland and pecan groves. However, extensive wetland riparian buffers intercept runoff along most of the Coastal Plain reach of the Flint River, thus mitigating the impact of agriculture on the reservoir's water quality.

The terminal reaches of both the Chattahoochee and Flint Rivers are impounded behind Jim Woodruff Dam, completed in 1954 by the Corps to form **Lake Seminole**, approximately 133 miles downstream from Columbus and 74 miles downstream from Albany. Bainbridge is located on the Flint River arm of the reservoir. Lake Seminole is used for flood control, hydropower generation, and navigation. Although much of Lake Seminole's watershed is predominantly cropland, the land area adjacent to the reservoir largely is forested. There is some urban influence on the water quality of the Flint arm from Albany and Bainbridge.



RESERVOIR (YEAR COMPLETED)	PREDOMINANT LAND USE	CORE THICKNESS, IN INCHES	SEDIMENTATION RATE, IN INCHES PER YEAR ¹
Lake Sidney Lanier (1956)— Chattahoochee River arm	Forested, poultry	8.7	0.22
West Point Lake (1974)	Urban	27.6	1.41
Lake Harding ² (1926)	Urban	88.6	1.35
Walter F. George Reservoir (1962)	Urban	58.3	1.82
Lake Blackshear (1927)	Cropland	27.6	0.41
Lake Seminole (1954)—Flint River arm	Cropland	38.6	0.96

¹ Sedimentation rates are assumed to be linear and are based on core length (not dry mass of deposited material).
² Pre-reservoir surface was not reached in Lake Harding. An age was assigned to the bottom of the core on the basis of the deposition rate for the 1952 to 1963–64 core interval.

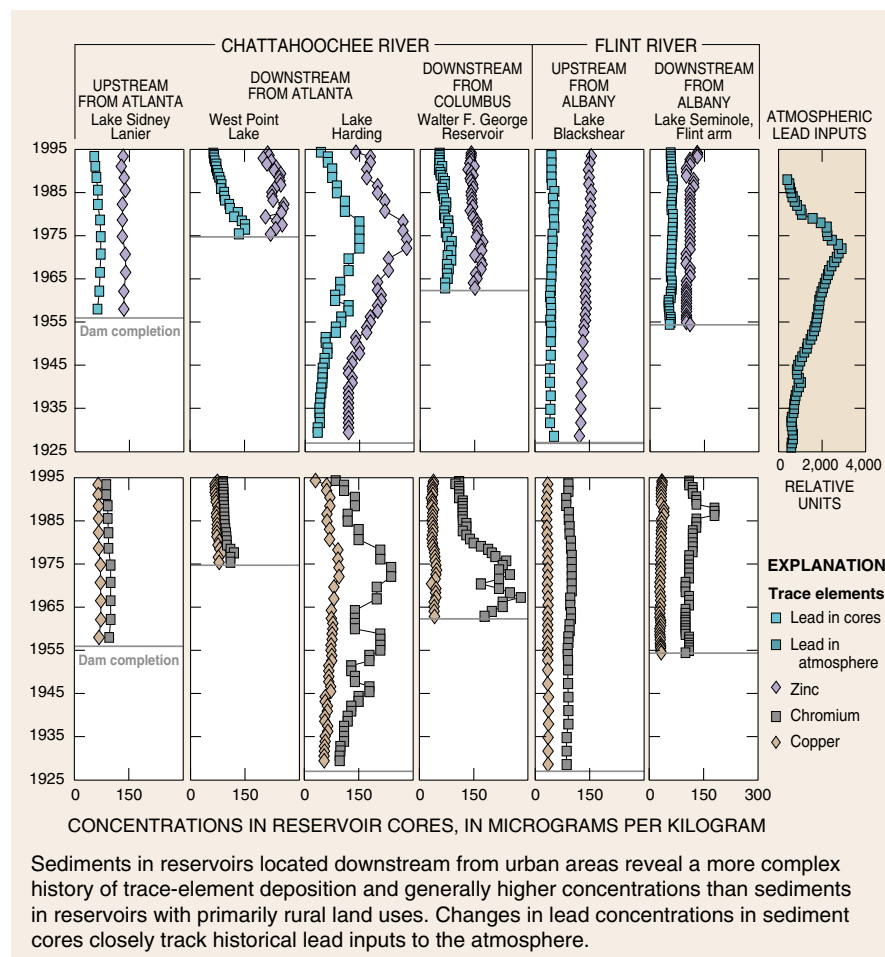
MAJOR ISSUES AND FINDINGS

Historical Trends in Water Quality Determined from Reservoir Cores

Age-dated depth profiles of lead, zinc, chromium, and copper concentrations in sediment cores show historical patterns of upstream urban and industrial activity, upstream reservoir construction, and regional atmospheric deposition. West Point Lake, Lake Harding, and Walter F. George Reservoir reveal a more complex history of trace-element pollution because they are most directly affected by upstream urban and industrial activities.

In Lake Harding sediments, lead and zinc concentrations began to increase beginning in the mid-1940's and more than doubled by the mid-1970's. Copper concentrations gradually increased through this same period. However, chromium concentrations peaked about 1945, during the mid-1950's, and again during the mid-1970's, with the highest concentrations measured during this latter period. Although industrial growth and development in Metropolitan Atlanta is a source for much of the increased deposition of metals to Lake Harding, additional emissions outside the ACF River Basin also contributed through regional atmospheric transport and deposition. Concentrations of all four metals generally decreased between the mid-1970's and the time the cores were collected in 1994. This recent trend coincides with the completion of West Point Dam and provides evidence that, with the exception of chromium, much of the pollutant load to Lake Harding prior to West Point's completion was derived from Metropolitan Atlanta.

Chromium concentrations in Lake Harding and Walter F. George Reservoir cores were the highest among the six reservoirs sampled. Concentrations in the Walter F. George core peaked during the late 1960's and again during the mid-1970's and then decreased in similar fashion to the pattern described for Lake Harding. However, concentrations of chromium in post-1975 sediments in both of these reservoirs are larger than those measured in West



Point Lake, indicating that local sources downstream from Atlanta are contributing part of the chromium load. Industrial effluent from the textile industry has been a major source of chromium (Förstner and Wittman, 1979), and there are several textile mills that discharge to the Chattahoochee River just upstream from Lake Harding and Walter F. George Reservoir.

Except for zinc in West Point Lake and zinc and copper in Walter F. George Reservoir, trace-element concentrations generally decreased after 1975 in all three urban reservoirs. The Clean Air and Clean Water Act legislation, requiring improved waste treatment and reduction strategies, were enacted about this time. Thus, some of the decrease in trace-element deposition to these reservoirs relates to compliance with these laws. This is

particularly true for lead. Leaded gasoline use peaked in 1972 and then declined through 1982 when lead compounds were banned from use in all new vehicles sold in the United States. This trend is shown by atmospheric lead inputs (Eisenreich and others, 1986) and in the reservoir cores, particularly West Point Lake and Lake Harding. The largest lead concentrations in reservoir sediments and the steepest lead declines are seen in the reservoirs closest to urban areas or with urban land areas upstream (Callender and Van Metre, 1997).

Lake Sidney Lanier, Lake Blackshear, and Lake Seminole, in contrast with the urban reservoirs, are less directly affected by local sources of pollutants. Historical trends in trace-element concentrations in these reservoirs largely relate to changes in the regional patterns of atmospheric deposition.

Sediment cores were analyzed for organochlorine insecticides, polychlorinated naphthalenes (PCNs), and polychlorinated biphenyls (PCBs). The only compounds detected in the cores were chlordane, DDT and its degradation products (DDD and DDE), and PCBs. Historical patterns in reservoir sediment concentrations of these compounds provide a record of changes in their use in urban and agricultural settings within the ACF River Basin.

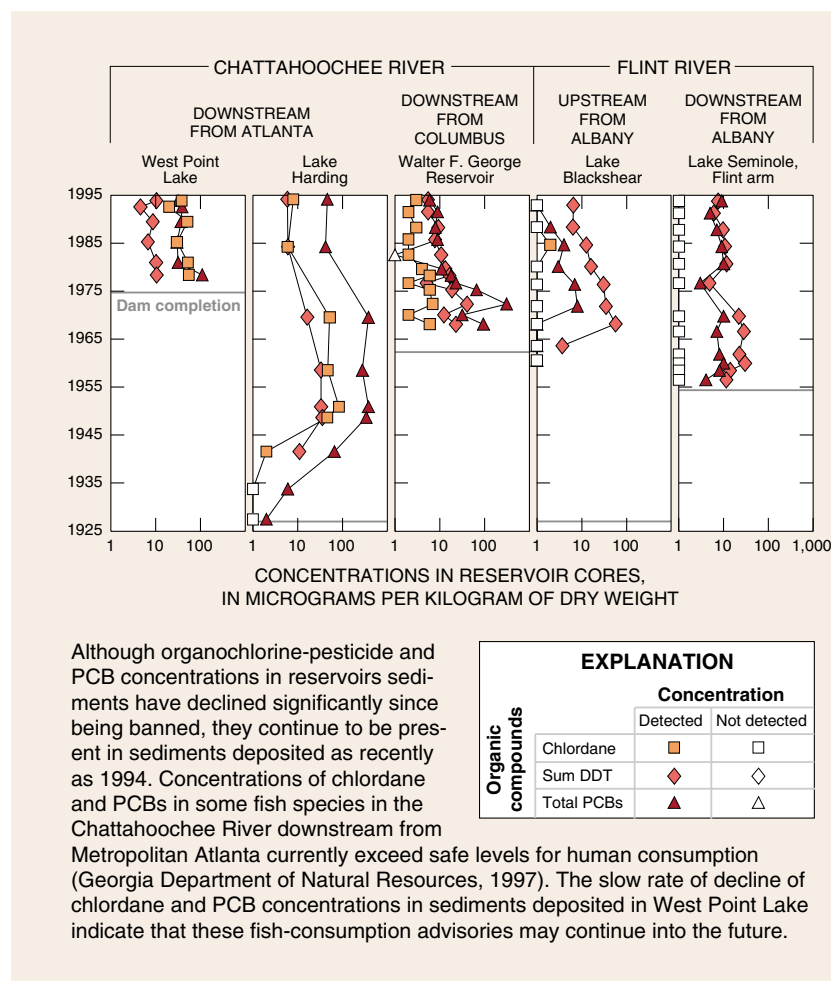
Chlordane was extensively used through the late 1980's as a termiticide. Measurable concentrations of chlordane in the Lake Harding core first occurred during the early 1940's, indicating that chlordane use in Metropolitan Atlanta began shortly after it was first produced as an insecticide. Chlordane concentrations in Lake Harding sediments increased through the early 1950's, remained at their highest levels through the early 1970's, and then decreased by about a factor of 10 between the mid-1980's and the time of sampling. Although use of chlordane was banned in 1988, the decrease in the recent section of core from Lake Harding probably is related more to the completion of West Point Dam and subsequent trapping of chlordane-contaminated sediments in West Point Lake. This interpretation is consistent with chlordane concentrations in the West Point Lake core being larger than post-1975 concentrations in the Lake Harding core. The Walter F. George Reservoir core had smaller but still measurable concentrations of chlordane, indicating that chlordane was also used in the Columbus area. Sale of chlordane for agricultural use ceased in 1974, and only one sample from Lake Blackshear and no samples from Lake Seminole had detectable concentrations of chlordane.

DDT was widely used throughout the ACF River Basin as an insecticide in urban and agricultural settings until its use was banned in 1973. Based on

historical patterns in the cores (excluding West Point Lake), it appears that urban and agricultural use of DDT peaked in the early 1950's and late 1960's, respectively. However, DDT continues to be deposited at similar concentrations in each of the reservoirs.

PCBs were first commercially produced in 1929 and widely used in transformers, capacitors, and electromagnets and as heat-transfer and hydraulic fluids until their manufacture was banned in 1979. PCB concentrations in the Lake Harding core began to increase shortly after the reservoir was created, reached maximum levels during the late 1940's through the late 1960's, and then decreased to much lower concentrations by the mid-1980's. The largest PCB concentration in the West Point

Lake core occurred about 1976. Concentrations in more recent sections of the core were approximately one-third of the maximum, indicating that PCB use was prevalent in Metropolitan Atlanta up to the time of the ban. Concentrations of PCBs in the Walter F. George Reservoir core decreased during the late 1970's. The patterns in these three urban reservoirs could be due to a combination of local sources and regional atmospheric transport. One of the two facilities that manufactured PCBs in the United States was located in Anniston, Alabama, to the northwest of these reservoirs. Historical patterns in the much smaller concentrations measured in the Lake Blackshear and Lake Seminole cores probably relate to regional patterns in atmospheric transport and deposition of PCBs.



MAJOR ISSUES AND FINDINGS

Biological Indicators of Water Quality

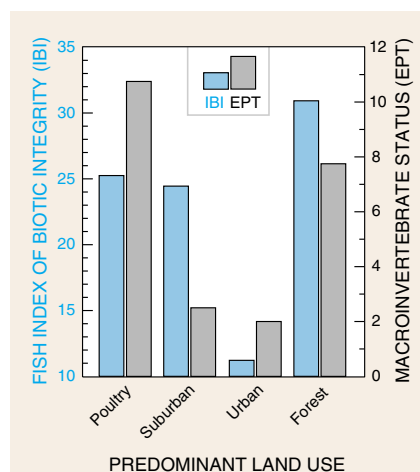
In the Piedmont Province, poultry production, suburban and urban land uses, and silviculture are human activities that influence the water quality of tributaries to the Chattahoochee and Flint Rivers. The biological condition of these tributaries are influenced by water-quality and hydrologic conditions that vary, depending on the type and intensity of human activities. Forested watersheds in the ACF River Basin are subject to less human activities than the other land uses studied, and although not pristine, the biological condition in streams draining forested watersheds may be the best attainable in the ACF River Basin.

Tributaries of the Chattahoochee River in the Piedmont are inhabited by 42 native and 8 non-native (introduced) fish species (Couch and others, 1995). Because fish distribute themselves in streams relative to the location of their preferred habitats, not all 50 species live in any one stream reach. In streams with forested watersheds, about 20 fish species may live in a typical stream reach. In comparison

Aquatic biological communities commonly are sensitive indicators of stream-water quality. In highly populated areas, evaluations of aquatic biological communities commonly are the only assessment approach that can account for (1) highly transient water-quality problems stemming from urban runoff, accidental spills, or periodic sewer overflows, and (2) the cumulative effects of a potentially wide range of chemical contaminants.

The biological condition of streams is evaluated within water-quality assessment programs by comparing the type, number, or abundance of species that comprise aquatic biological communities to that of streams known to be pristine or to be least influenced by human activities. In this study, the biological condition of streams was measured using fish and benthic macroinvertebrate (adult and larval insects, crustaceans) communities in stream reaches representing predominant land uses in the watershed.

Two separate indices were used. The first index, an **Index of Biotic Integrity (IBI)**, is based on fish community data. IBI scores for a given stream were derived by summing scores of several separate factors that describe fish communities (DeVivo and others, 1997). Examples of such factors are the number of insect-eating and omnivorous (generalized-feeding) fish, the number of native sucker and minnow species, and the number of non-native species. The second index, an **EPT Index**, is based on the abundance of selected orders of pollution-sensitive insect larvae. It is the sum of the number of families within the insect orders of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) found in a stream reach. Streams with higher IBI and EPT index scores are indicative of better biological conditions than streams with lower scores.



In the Piedmont Physiographic Province of ACF River Basin, stream biological communities are most degraded in areas of suburban and urban land use. Fish communities show the most degradation in streams draining areas of urban land use, whereas macroinvertebrate communities are degraded in streams draining areas of suburban and urban land use.

to streams draining watersheds with predominantly poultry, suburban, or urban land use, streams with forested land use had the best biological condition as shown by the Index of Biotic Integrity (IBI, described above).

Although streams in predominantly forested watersheds are periodically disturbed by timber harvesting, these watersheds do not have high yields of nutrients or sediments (page 15) that influence biological conditions by altering stream habitats or food resources and do not contain the wide range of chemical and microbial contaminants present in streams draining predominantly suburban and urban watersheds (page 10). IBI scores indicate a similar level of degraded biological conditions for streams draining watersheds with predominantly poultry and suburban land use. Streams draining watersheds with predominantly urban land use had severely degraded biological conditions.

The macroinvertebrate status of streams draining watersheds with predominantly forested and poultry land use were relatively high as measured by the EPT Index (described above) scores, indicating markedly better biological conditions in these streams than in streams draining watersheds with predominantly suburban or urban land use. Poor habitat, high stormflows, and the presence of chemical contaminants, such as insecticides, may contribute to the loss of pollution-intolerant insect species in the streams draining watersheds with predominantly suburban and urban land use. The higher EPT Index scores in streams draining watersheds with predominantly poultry land use may be related to high nutrient inputs that increase the availability or variety of food resources beyond what is present in streams draining watersheds with predominantly forested land use.

As the human population of Metropolitan Atlanta continues to increase, forest and pasture land is being developed for suburban or urban use. Fish IBI scores for 21 tributaries of the Chattahoochee River that varied in the extent of urban development as measured by human population density show an immediate decline in biological condition with the onset of suburban and urban development (DeVivo and others, 1997).

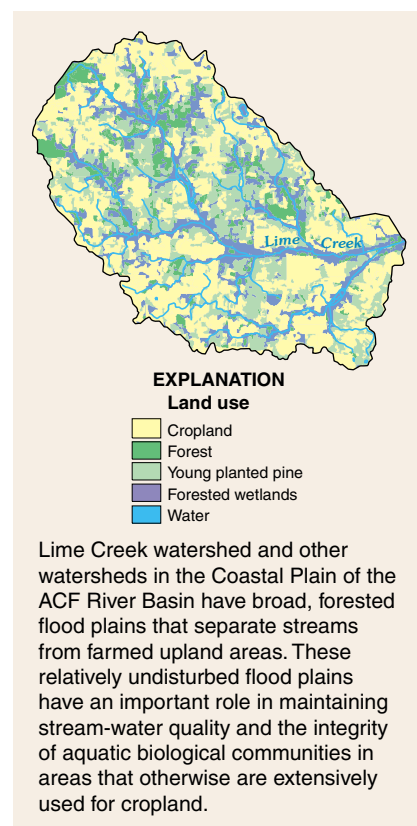
Watersheds with higher population densities generally had lower fish IBI scores, indicating poorer biological condition. Streams in areas of predominantly suburban or urban land use generally had less than one-half the number of fish species present in streams in areas of predominantly forested land use, and as many as 90 percent of the fish in urban streams were introduced. Species that survive outside of their native streams often thrive where water quality or habitat is degraded. Native minnow and sucker species were all but absent in urban streams. Minnows are important in the aquatic food chain as prey for larger

fish, aquatic snakes, turtles, and wading birds. Although suckers are not popular game fish, they are ecologically important because they often account for the largest fish biomass in healthy Piedmont streams. Streams draining urban lands in Metropolitan Atlanta contain elevated concentrations of nutrients (page 14) and a variety of chemical contaminants such as pesticides and trace elements (pages 10–11 and 19). Periodic discharges from combined sewers or broken or clogged sanitary sewers carry additional chemical and microbial contaminants into nearby streams. However, most nutrients and chemical contaminants enter streams as storm runoff from impervious surfaces (streets, parking lots) or as groundwater discharge that has percolated through landscaped areas. The degraded biological condition of urban streams results from the cumulative effects of high stormflows and exposure to a variety of contaminants.

The Coastal Plain of the ACF River Basin is composed of cropland and silvicultural land in upland areas and extensive and continuous forested wetlands in river bottoms. Relatively undisturbed riparian flood-plain and wetland habitats are present throughout this area. This contrasts to many other intensively farmed areas of the Nation where wetlands have been drained, channelized, or filled, and little or no riparian buffers remain between cropland and streams.

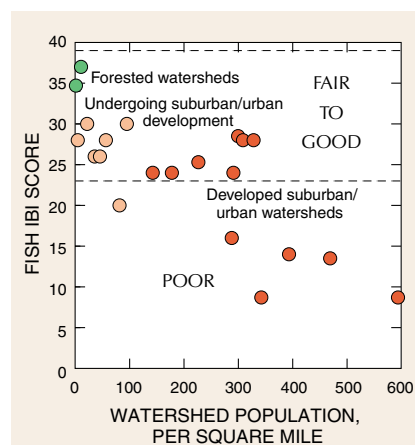
Flood-plain wetlands provide many ecological benefits such as dissipating the energy of floods, reducing erosion, and stabilizing the streamside environment. Winter and spring flooding is a normal occurrence in Coastal Plain streams, and many fish species use the flood plains as spawning, nursery, and foraging areas.

In July 1994, flooding from Tropical Storm Alberto resulted in streamflows that exceeded the 100-year recurrence interval throughout the Flint River



Basin (page 9). The flood occurred outside of the normal period of seasonal flooding. The ACF River Basin NAWQA investigated the influence of this flood on the fish community of Lime Creek, a stream located in the area that received a large amount of rainfall from Tropical Storm Alberto. The fish-community surveys were performed before the flood and for a 2-year period after the flood.

Thirty-two fish species were identified during the sampling period. Although an IBI has not been developed for Coastal Plain fish communities, the number and diversity of fish species in Lime Creek indicate a healthy fish community. The flood did not result in a catastrophic loss of fish species. All but one fish species present in Lime Creek before the flood were also present after the flood. The potential disturbance to the fish community was lessened by the forested flood-plain wetlands that remain intact in a watershed that is otherwise predominantly cropland.

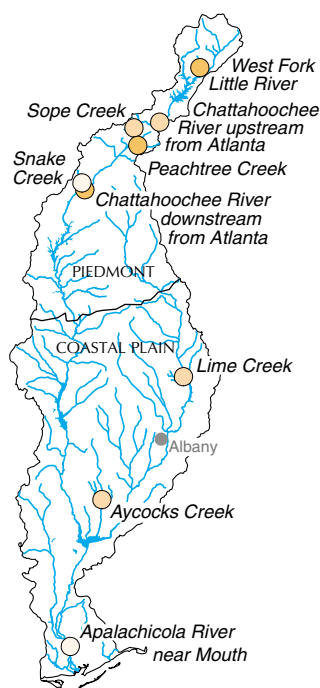


In the Piedmont, fish communities are degraded by increasing urban development. In forested watersheds, streams have fish communities that are represented by a diversity of mostly native species with varied tolerance to pollution. As watersheds are developed, fish communities in streams are dominated by pollution-tolerant, mostly non-native species.

WATER-QUALITY CONDITIONS IN A NATIONAL CONTEXT

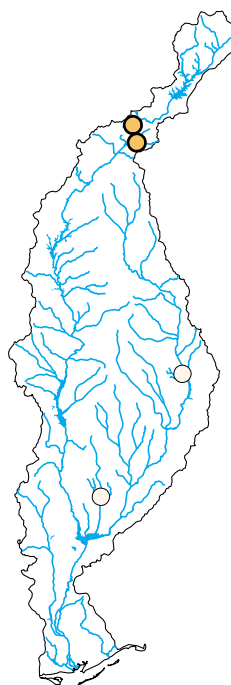
Comparison of Stream-Water Quality in the Apalachicola–Chattahoochee–Flint River Basin with Nationwide NAWQA Findings

Seven major water-quality characteristics were evaluated for stream sites in each NAWQA Study Unit. Summary scores for each characteristic were computed for all sites that had adequate data. Scores for each site in the ACF River Basin were compared with scores for all sites sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA sites. Water-quality conditions at each site also are compared to established criteria for protection of aquatic life. Applicable criteria are limited to nutrients and pesticides in water, and semivolatile organic compounds, organochlorine pesticides and PCBs in sediment. (Methods used to compute rankings and evaluate aquatic-life criteria are described by Gilliom and others, *in press*.)



NUTRIENTS IN WATER

Median nutrient concentrations at nine streams were generally lower in the ACF River Basin than for 219 NAWQA sites ranked nationally. Median phosphorus concentrations were only above national medians downstream from Atlanta. Nitrate concentrations were highest at the poultry site (West Fork Little River) and the Chattahoochee River downstream from Atlanta. Like most of the United States (Mueller and others, 1995), all nitrate concentrations in surface water in the ACF River Basin were well below the drinking-water standard. Ammonia concentrations were highest downstream from Atlanta and at the urban site (Peachtree Creek). Aquatic-life criteria for ammonia were not exceeded at these nine sites during the study period.



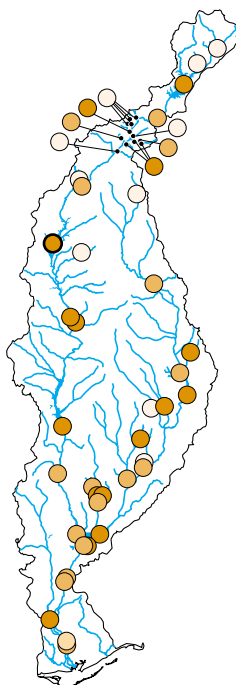
PESTICIDES IN WATER

Pesticide levels at the urban (Peachtree Creek) and suburban (Sope Creek) sites were in the third quartile of 61 NAWQA sites ranked nationally, primarily because insecticides were frequently detected. Median monthly concentrations of the insecticides diazinon and carbaryl exceeded aquatic-life criteria at the urban and suburban sites, and chlorpyrifos exceeded aquatic-life criteria at the urban site. Pesticide scores at the cropland sites (Lime and Aycocks Creeks) were in the lowest quartile of NAWQA sites, although pesticide use is widespread in these areas.

EXPLANATION

Ranking of stream quality relative to all NAWQA stream sites—Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more aquatic life criteria were exceeded.

- Greater than the 75th percentile (among the highest 25 percent of NAWQA stream water studies)
- Between the median and the 75th percentile
- Between the 25th percentile and the median
- Less than the 25th percentile (among the lowest 25 percent of NAWQA stream water studies)



ORGANOCHLORINE PESTICIDES AND PCBs IN BED SEDIMENT AND BIOLOGICAL TISSUE

The scores for organochlorine pesticides and PCBs (sediment and tissue data combined) at 71 percent of ACF River Basin sites were higher than the median score of 202 NAWQA sites. Higher scores in the ACF River Basin were primarily at urban, cropland, and mixed land-use sites. DDT* or its degradation products (DDD, DDE) were detected in 41 percent of tissue samples and 52 percent of bed-sediment samples; however, concentrations measured in 1992–94 generally were lower than those reported in historical data (1965–91). The termiticides chlordane* and dieldrin* were primarily detected at sites associated with urban areas. The fire-ant-control insecticide mirex* was detected at four agricultural sites in the Coastal Plain. Organochlorine pesticides and PCBs* were not detected in poultry, forested, and six of seven suburban sites sampled. West Point Lake bed sediment had the only exceedances of aquatic-life criteria for organochlorine insecticides (total chlordane) and PCBs within the ACF River Basin.

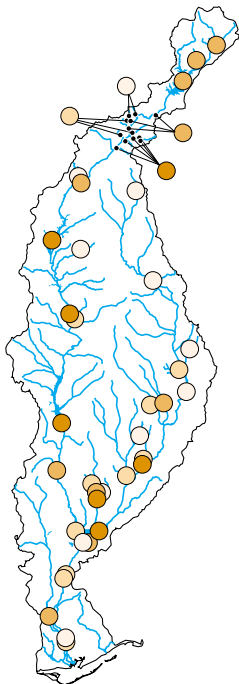
*Used extensively in the Southeastern United States prior to legal uses being banned: DDT, 1973; chlordane, 1974 (agriculture), 1988 (termiticide); dieldrin, 1974 (agriculture), 1987 (termiticide); mirex, 1976; and PCBs, 1979.

WATER-QUALITY CONDITIONS IN A NATIONAL CONTEXT

Comparison of Stream-Water Quality in the Apalachicola–Chattahoochee–Flint River Basin with Nationwide NAWQA Findings

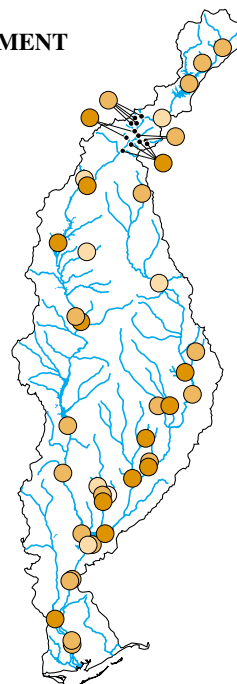
SEMIVOLATILE ORGANIC COMPOUNDS IN BED SEDIMENT

Semivolatile organic compound (SVOC) concentrations in the ACF River Basin were highest in tributary streams in areas of urban land use and in main-stem rivers downstream from Metropolitan Atlanta and Albany. SVOC concentrations were relatively low at poultry, suburban, forested, and cropland sites. The distribution of SVOC standardized scores in the ACF River Basin are similar to 198 NAWQA sites ranked across the Nation. No exceedances of aquatic-life criteria for SVOCs were measured within the ACF River Basin.



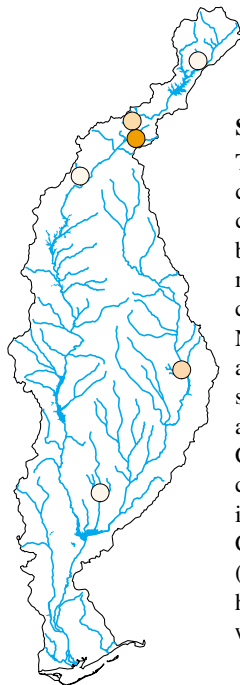
TRACE ELEMENTS IN BED SEDIMENT

Trace-element concentrations of zinc, cadmium, lead, copper, and mercury in bed sediment were highest downstream from urban areas in the ACF River Basin. Concentrations of arsenic, nickel, and chromium were elevated at some agricultural sites in the Coastal Plain. The trace-element scores for 41 of 48 sites (85 percent) in the ACF River Basin were above the median for 198 NAWQA sites. Although trace elements occur naturally in rocks and sediments, measured concentrations in bed sediments at many of these sites were enriched relative to background conditions.



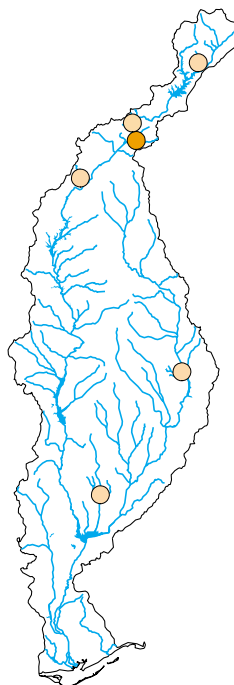
STREAM HABITAT DEGRADATION

The capacity of a stream to support biological communities is influenced by physical habitat characteristics including the stability of stream-banks, the presence of riparian buffers, and modifications such as channelization. In comparison to 181 NAWQA sites across the Nation, two agricultural sites (Aycocks Creek and West Fork Little River) and one forested site (Snake Creek) in the ACF River Basin had among the best and one urban site (Peachtree Creek) had among the worst stream-habitat conditions. Two sites were not among the best in the Nation because an agricultural site (Lime Creek) was channelized and the suburban site (Sope Creek) had eroding streambanks. Stream habitat was not evaluated at large river sites within the ACF River Basin.



FISH COMMUNITY DEGRADATION

Increasing percentages of diseased, pollution-tolerant, omnivorous, and non-native fish are generally associated with degraded fish communities. The status of fish communities at five out of six sites in the ACF River Basin were ranked better than the median for 172 NAWQA sites. The fish community at the urban site (Peachtree Creek) was among the most degraded of sites across the Nation. Fish communities were not evaluated at large river sites within the ACF River Basin.



CONCLUSIONS

Compared with other NAWQA Study Units, in the Apalachicola-Chattahoochee-Flint (ACF) River Basin:

- Urban tributaries and the Chattahoochee River downstream from Atlanta were among the most degraded sites evaluated by NAWQA during 1992–95. Suburban and agricultural (cropland and poultry) tributaries and the Chattahoochee River upstream from Atlanta showed varying degrees of degradation that were comparable to many sites evaluated in the Nation. A forested tributary and the Apalachicola River were among the least-degraded sites evaluated in the Nation.
- Aquatic-life criteria for bed sediment were exceeded downstream from Atlanta in West Point Lake (chlordane and PCBs).
- Aquatic-life criteria for surface water were exceeded by median monthly concentrations of insecticides in the urban site, Peachtree Creek (three insecticides), and the suburban site, Sope Creek (two insecticides).

WATER-QUALITY CONDITIONS IN A NATIONAL CONTEXT

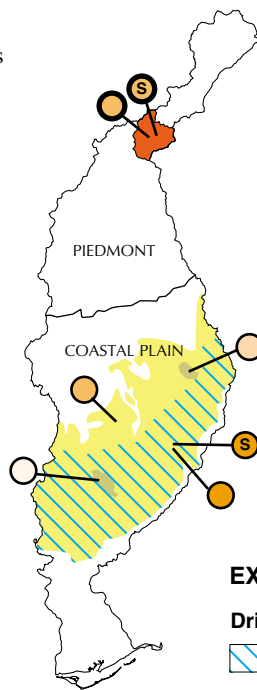
Comparison of Ground-Water Quality in the Apalachicola–Chattahoochee–Flint River Basin with Nationwide NAWQA Findings

Five major water-quality characteristics were evaluated for ground-water studies in each NAWQA Study Unit. Ground-water resources were divided into two categories: (1) drinking-water aquifers, and (2) shallow ground water underlying agricultural or urban areas. Summary scores were computed for each characteristic for all aquifers and shallow ground-water areas that had adequate data. Scores for each aquifer and shallow ground-water area in the ACF River Basin were compared with scores for all aquifers and shallow ground-water areas sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentile values may indicate poorer quality compared with other NAWQA ground-water studies. Water-quality conditions for each drinking-water aquifer also are compared to established drinking-water standards and criteria for protection of human health. (Methods used to compute rankings and evaluate standards and criteria are described by Gilliom and others, *in press*.)



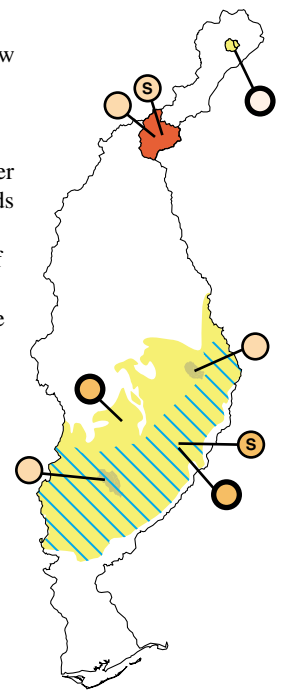
PESTICIDES

For five ground-water study components in the ACF River Basin, one or more pesticides were detected at 57 to 81 percent of sites sampled, placing these components in the highest two quartiles compared to other NAWQA ground-water study areas. Highly sensitive analytical methods have shown that low concentrations of some widely used pesticides are present in shallow ground water underlying urban and suburban areas, cropland, and the Upper Floridan aquifer. However, pesticide concentrations in ground water rarely exceeded drinking-water standards or guidelines. The banned insecticide, dieldrin, exceeded the current drinking-water guideline in water samples from 5 of 37 locations in suburban and urban land use in Metropolitan Atlanta. The source of this persistent compound probably is residual quantities of dieldrin and aldrin that were applied prior to 1987 for termite control of homes and commercial buildings.



NITRATE

Nitrate generally is present in shallow aquifers in the ACF River Basin. Median nitrate concentrations in the ACF River Basin were typical of those in other NAWQA ground-water study areas. Drinking-water standards for nitrate were exceeded in water samples from less than 10 percent of wells near poultry production and cropland and the recharge area to the Upper Floridan aquifer. No exceedances occurred in ground-water samples from wells and springs in Metropolitan Atlanta or in springs from the Upper Floridan aquifer.



EXPLANATION

Drinking-water aquifer

Upper Floridan aquifer

Shallow ground-water areas

Cropland—Darker color represents area with a higher density of wells sampled

Urban and suburban

Ranking of ground-water quality relative to all NAWQA ground-water studies—Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more standards or criteria were exceeded.

"s" indicates spring data

Greater than the 75th percentile (among the highest 25 percent of NAWQA ground-water studies)

Between the median and the 75th percentile

Between the 25th percentile and the median

Less than the 25th percentile (among the lowest 25 percent of NAWQA ground-water studies)

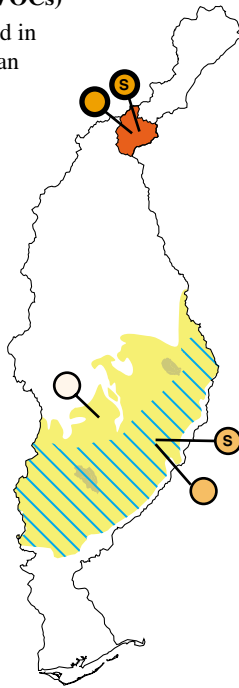
WATER-QUALITY CONDITIONS IN A NATIONAL CONTEXT

Comparison of Ground-Water Quality in the Apalachicola–Chattahoochee–Flint River Basin with Nationwide NAWQA Findings

VOLATILE ORGANIC COMPOUND (VOCs)

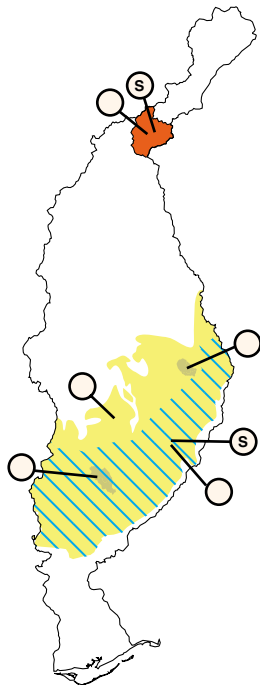
In Metropolitan Atlanta, VOCs were detected in ground-water samples from slightly more than 50 percent of the sites sampled, placing this study area in the highest quartile for springs and wells compared to other NAWQA ground-water study areas. Twenty-six VOCs commonly associated with fuel products, industrial chemicals, solvents, and degreasers were detected. Chloroform, the most commonly detected VOC, is a by-product of disinfecting drinking water with chlorine and may be present in ground-water recharge from septic systems and leaking water and sewer lines. Concentrations of tetrachloroethene (used extensively in the dry cleaning industry) and benzene and naphthalene (components of gasoline) exceeded drinking-water standards in ground-water samples from 3 of 37 sites sampled.

In the Coastal Plain, VOCs were detected in ground-water samples from approximately 15 percent of wells and springs in the Upper Floridan aquifer and in only 1 of 37 wells in shallow ground-water areas near cropland, placing these study components in the third and first quartiles, respectively. VOCs detected include compounds present in gasoline, compounds used as degreasers or solvents, and the banned soil fumigant 1,2-dichloropropane.



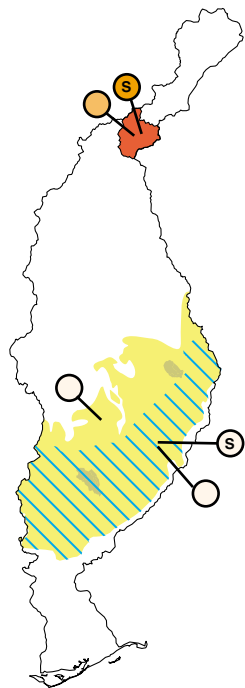
DISSOLVED SOLIDS

Low dissolved-solids concentrations placed all the ACF ground-water study areas in the lowest quartile compared to other NAWQA study areas. Dissolved-solids concentrations in ground water are generally related to climatic conditions and the composition of rocks and soils more than land use. Dissolved-solids concentrations generally are low in the ACF River Basin because there is plentiful rainfall and most aquifer materials are only slightly soluble in water.



RADON

Radon is a short-lived radioactive gas that is common in ground water. It is introduced into ground water by the radioactive decay of uranium present in aquifer materials and soils. Therefore, the occurrence of radon is controlled to a great extent by bedrock geology—not land use. Metropolitan Atlanta is underlain by igneous and metamorphic rocks that generally contain higher concentrations of uranium than most other rock types in the Study Unit and the Nation. Median radon concentrations in shallow ground water in Metropolitan Atlanta were in the highest quartile for springs and the third quartile for wells compared to other NAWQA ground-water study areas. Median radon concentrations in the studies within sediments of the Coastal Plain Physiographic Province were in the lowest quartile.



CONCLUSIONS

Compared with other NAWQA Study Units, in the Apalachicola–Chattahoochee–Flint River Basin:

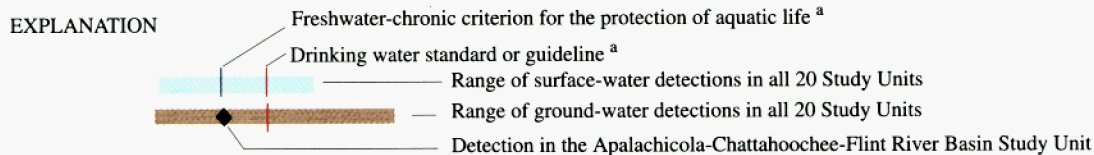
- Median nitrate concentrations in the ground-water study areas varied from the lowest to the third highest quartile of the NAWQA study areas across the Nation; however, nitrate concentrations only rarely exceeded the drinking-water standard in samples from wells (located near cropland and in the Upper Floridan aquifer) and did not exceed the standard in samples from springs.
- Pesticides and VOCs were detected more frequently in ground-water samples from Metropolitan Atlanta and the Upper Floridan aquifer than in most NAWQA study areas across the Nation. Although traces of these compounds are widely distributed in ground water from these study areas, the only exceedances of drinking-water standards occurred in samples from three springs and five wells located in Metropolitan Atlanta. These exceedances in shallow ground water in Metropolitan Atlanta indicate a potential water-quality concern for developing future public drinking-water supplies in the underlying fractured-rock aquifer.

SUMMARY OF COMPOUND DETECTIONS AND CONCENTRATIONS

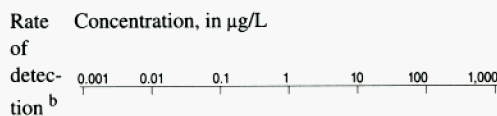
The following tables summarize data collected for NAWQA studies from 1992–1995 by showing results for the Apalachicola-Chattahoochee-Flint River Basin Study Unit compared to the NAWQA national range for each compound detected. In order to represent the wide concentration ranges observed among Study Units, logarithmic scales are used to emphasize the general magnitude of concentrations—such as 10, 100, or 1,000—rather than the precise number. The complete dataset used to construct these tables is available upon request.

Concentrations of herbicides, insecticides, volatile organic compounds, nutrients, and radon detected in ground and surface waters of the Apalachicola-Chattahoochee-Flint River Basin Study Unit

[mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; %, percent; <, less than; —, not measured]

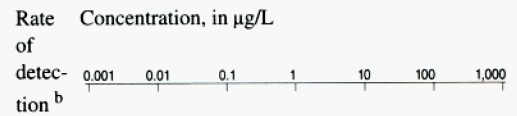


Herbicide



Alachlor	4% 16%	
2,6-Diethylaniline (Alachlor metabolite)	0% <1%	
Atrazine	51% 18%	
Deethylatrazine ^c (Atrazine metabolite)	2% 17%	
Benfluralin	4% 0%	
Bentazon	1% <1%	
Bromacil	4% 2%	
Butylate	<1% 1%	
Cyanazine	11% 6%	
2,4-D	7% 0%	
2,4-DB	<1% 0%	
DCPA	<1% 0%	
Dicamba	<1% <1%	
Diuron	11% 1%	
Ethalfuralin	<1% 0%	
Fluometuron	11% 19%	

Herbicide



Linuron	<1% <1%	
MCPA	3% 0%	
MCPB	<1% 0%	
Metolachlor	17% 11%	
Metribuzin	4% <1%	
Napropamide	1% 0%	
Norflurazon	3% 6%	
Oryzalin	1% 0%	
Pendimethalin	10% <1%	
Prometon	20% 2%	
Pronamide	3% 0%	
Propachlor	<1% 1%	
Propanil	<1% 0%	
Simazine	49% 1%	
Tebuthiuron	35% 2%	
Terbacil ^c	<1% 0%	

SUMMARY OF COMPOUND DETECTIONS AND CONCENTRATIONS

Herbicide

Rate of detection^b Concentration, in µg/L

0.001 0.01 0.1 1 10 100 1,000

Triclopyr	<1% 0%	
Trifluralin	5% 2%	

Insecticide

Rate of detection^b Concentration, in µg/L

0.001 0.01 0.1 1 10 100 1,000

Aldicarb sulfone ^c (Aldicarb metabolite)	0% <1%	
Aldicarb sulfoxide ^c (Aldicarb metabolite)	<1% 1%	
Azinphos-methyl ^c	<1% 0%	
Carbaryl ^c	24% <1%	
Carbofuran ^c	<1% 0%	
Chlorpyrifos	13% <1%	
p,p'-DDE (DDT metabolite)	<1% <1%	
Diazinon	24% <1%	
Dieldrin	<1% 4%	
Disulfoton ^c	<1% 0%	
Ethoprop	<1% 0%	
Fonofos	3% <1%	
alpha-HCH	<1% 0%	
gamma-HCH	<1% 0%	
Malathion	6% <1%	
Parathion	<1% 0%	
Propoxur	<1% <1%	
Terbufos	0% <1%	

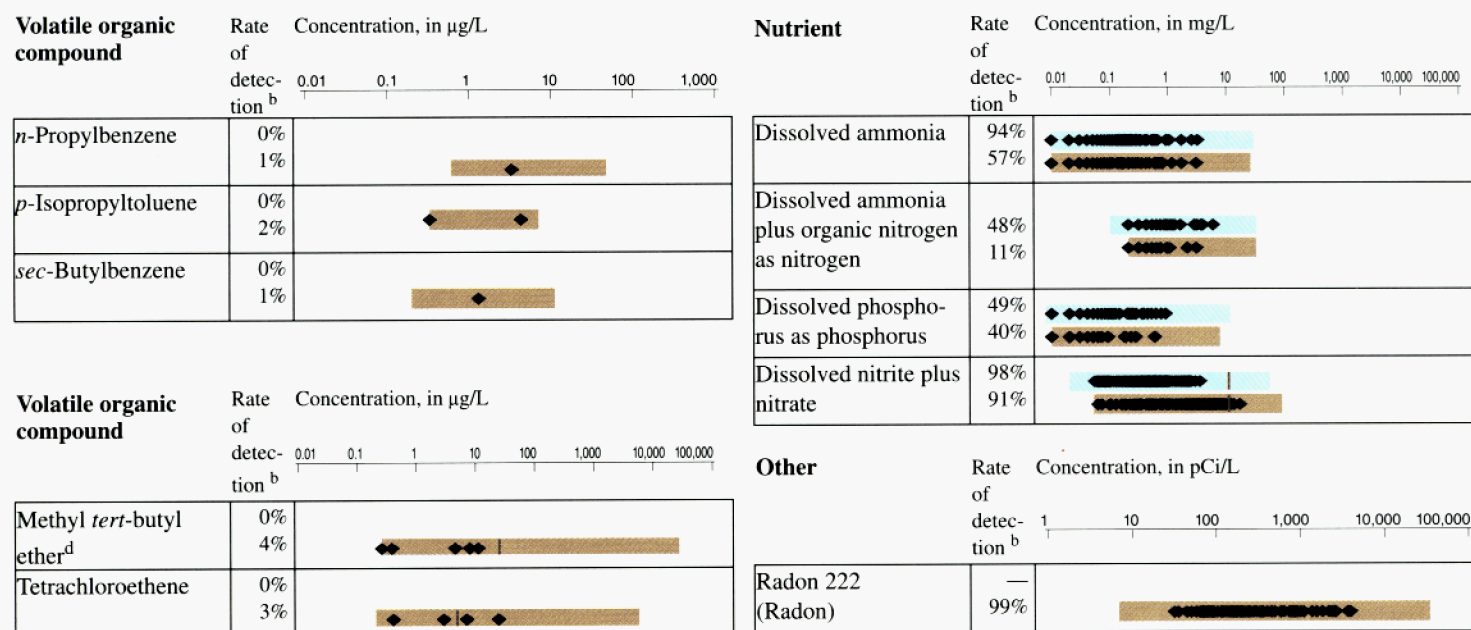
Volatile organic compound

Rate of detection^b Concentration, in µg/L

0.01 0.1 1 10 100 1,000

1,1,1-Trichloroethane	0% 2%	
1,1-Dichloroethane	0% 3%	
1,1-Dichloroethene	0% 1%	
1,2,4-Trimethylbenzene	0% 3%	
1,2-Dichloroethane	0% 3%	
1,2-Dichloropropane	0% 1%	
1,3,5-Trimethylbenzene	0% 2%	
1,4-Dichlorobenzene	0% 2%	
Benzene	0% 4%	
Chlorobenzene	0% 1%	
Chloromethane	11% 1%	
Dichlorodifluoromethane	0% 1%	
Dimethylbenzenes	0% 5%	
Ethylbenzene	0% 2%	
Isopropylbenzene	0% 1%	
Methylbenzene	0% 3%	
Naphthalene	0% 3%	
Tetrachloromethane	0% 2%	
total Trihalomethanes	0% 12%	
Trichloroethene	0% 3%	
Trichlorofluoromethane	0% 3%	
cis-1,2-Dichloroethene	0% 3%	
n-Butylbenzene	0% 1%	

SUMMARY OF COMPOUND DETECTIONS AND CONCENTRATIONS



Herbicides, insecticides, and volatile organic compounds not detected in ground and surface waters of the Apalachicola-Chattahoochee-Flint River Basin Study Unit.

Herbicides	Molinate	Methyl parathion	1,2,3-Trichlorobenzene	Bromochloromethane
2,4,5-T	Neburon	Oxamyl	1,2,3-Trichloropropane	Bromomethane
2,4,5-TP	Pebulate	Phorate	1,2,4-Trichlorobenzene	Chloroethane
Acetochlor	Picloram	Propargite	1,2-Dibromo-3-chloropropane	Chloroethene
Acifluorfen	Propham	<i>cis</i> -Permethrin	1,2-Dibromoethane	Dibromomethane
Bromoxynil	Thiobencarb	Volatile organic compounds	1,2-Dichlorobenzene	Dichloromethane
Chloramben	Triallate	1,1,1,2-Tetrachloroethane	1,3-Dichlorobenzene	Ethynylbenzene
Clopyralid	Insecticides	1,1,2,2-Tetrachloroethane	1,3-Dichloropropane	Hexachlorobutadiene
Dacthal mono-acid (Dacthal metabolite)	3-Hydroxycarbofuran (Carbofuran metabolite)	1,1,2-Trichloro-1,2,2-trifluoroethane	1-Chloro-2-methylbenzene	<i>cis</i> -1,3-Dichloropropene
Dichlorprop	Aldicarb	1,1,2-Trichloroethane	1-Chloro-4-methylbenzene	<i>tert</i> -Butylbenzene
Dinoseb	Methiocarb	1,1-Dichloropropene	2,2-Dichloropropane	<i>trans</i> -1,2-Dichloroethene
EPTC	Methomyl		Bromobenzene	<i>trans</i> -1,3-Dichloropropene
Fenuron				

^a Selected water-quality standards and guidelines and sediment-quality guidelines (Gilliom and others, *in press*).

^b Rates of detection are based on the number of analyses and detections in the Study Unit, not on national data. Rates of detection for herbicides and insecticides were computed by only counting detections equal to or greater than 0.01 µg/L in order to facilitate equal comparisons among compounds, which had widely varying detection limits. For herbicides and insecticides, a detection rate of "<1%" means that all detections are less than 0.01 µg/L, or the detection rate rounds to less than 1 percent. For other compound groups, all detections were counted and minimum detection limits for most compounds were similar to the lower end of the national ranges shown. Method detection limits for all compounds in these tables are summarized in Gilliom and others (*in press*).

^c Detections of these compounds are reliable, but concentrations are determined with greater uncertainty than for the other compounds and are reported as estimated values (Zaugg and others, 1995).

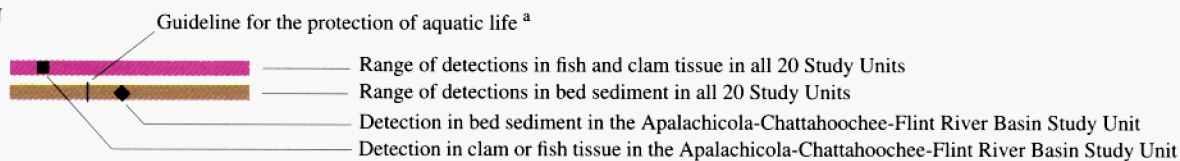
^d The guideline for methyl *tert*-butyl ether is between 20 and 40 µg/L; if the tentative cancer classification C is accepted, the lifetime health advisory will be 20 µg/L (Gilliom and others, *in press*).

SUMMARY OF COMPOUND DETECTIONS AND CONCENTRATIONS

Concentrations of semivolatile organic compounds, organochlorine compounds, and trace elements detected in clam and fish tissue and bed sediment of the Apalachicola-Chattahoochee-Flint River Basin Study Unit

[µg/g, micrograms per gram; µg/kg, micrograms per kilogram; %, percent; <, less than; —, not measured]

EXPLANATION



Semivolatile organic compound

Rate of detection ^b Concentration, in µg/kg

0.1 1 10 100 1,000 10,000 100,000

1,2-Dimethylnaphthalene	—	4%	
1,6-Dimethylnaphthalene	—	15%	
1-Methyl-9H-fluorene	—	7%	
1-Methylphenanthrene	—	25%	
1-Methylpyrene	—	22%	
2,2-Biquinoline	—	1%	
2,3,6-Trimethylnaphthalene	—	13%	
2,6-Dimethylnaphthalene	—	37%	
2,6-Dinitrotoluene	—	6%	
2-Ethyl-naphthalene	—	6%	
2-Methylantracene	—	9%	
4,5-Methylenepheneanthrene	—	28%	
9H-Carbazole	—	19%	
9H-Fluorene	—	22%	
Acenaphthene	—	7%	
Acenaphthylene	—	18%	
Acridine	—	18%	

Semivolatile organic compound

Rate of detection ^b Concentration, in µg/kg

0.1 1 10 100 1,000 10,000 100,000

Anthracene	—	36%	
Anthraquinone	—	31%	
Azobenzene	—	1%	
Benz[a]anthracene	—	43%	
Benzo[a]pyrene	—	42%	
Benzo[b]fluoranthene	—	48%	
Benzo[ghi]perylene	—	27%	
Benzo[k]fluoranthene	—	48%	
Butylbenzylphthalate	—	60%	
Chrysene	—	46%	
Di- n -butylphthalate	—	91%	
Di- n -octylphthalate	—	31%	
Dibenz[a,h]anthracene	—	18%	
Dibenzothiophene	—	13%	
Diethylphthalate	—	69%	
Dimethylphthalate	—	6%	
Fluoranthene	—	61%	

SUMMARY OF COMPOUND DETECTIONS AND CONCENTRATIONS

Semivolatile organic compound

Rate of detection^b Concentration, in µg/kg
0.1 1 10 100 1,000 10,000 100,000

Indeno[1,2,3- <i>cd</i>] pyrene	— 39%	
Isophorone	— 1%	
Isoquinoline	— 3%	
Naphthalene	— 13%	
<i>N</i> -Nitrosodi- <i>n</i> -propylamine	— 1%	
<i>N</i> -Nitrosodi-phenylamine	— 1%	
Phenanthrene	— 48%	
Phenanthridine	— 10%	
Phenol	— 73%	
Pyrene	— 63%	
bis(2-Chloroethoxy)methane	— 1%	
bis(2-Ethylhexyl)phthalate	— 82%	
<i>p</i> -Cresol	— 52%	

Organochlorine compound

Rate of detection^b Concentration, in µg/kg
0.01 0.1 1 10 100 1,000 10,000 100,000

Aldrin	0% 1%	
total-Chlordane (Chlordane)	10% 13%	
<i>p,p'</i> -DDE	45% 48%	
total-DDT	45% 52%	
Dieldrin	10% 6%	
<i>beta</i> -HCH	3% 1%	
Heptachlor epoxide (heptachlor metabolite)	3% 0%	
Mirex	0% 6%	
PCB, total	6% 4%	

Trace element

Rate of detection^b Concentration, in µg/g
0.01 0.1 1 10 100 1,000 10,000

Arsenic	100% 100%	
Cadmium	97% 99%	
Chromium	100% 100%	
Copper	100% 100%	
Lead	48% 100%	
Mercury	88% 100%	
Nickel	88% 100%	
Selenium	85% 100%	
Zinc	100% 100%	

Semivolatile organic compounds and organochlorine compounds not detected in clam and fish tissue and bed sediment of the Apalachicola-Chattahoochee-Flint River Basin Study Unit.

Semivolatile organic compounds

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
3,5-Dimethylphenol
4-Bromophenyl-phenylether
4-Chloro-3-methylphenol
4-Chlorophenyl-phenylether

Benzo [c] cinnoline

C8-Alkylphenol

Nitrobenzene

Pentachloronitrobenzene

Quinoline

Organochlorine compounds

Chloroneb

DCPA

Endosulfan I

Endrin

Heptachlor

Hexachlorobenzene

Isodrin

Pentachloroanisole
pentachlorophenol
metabolite)

Toxaphene

alpha-HCH

cis-Permethrin

delta-HCH

gamma-HCH

o,p'-Methoxychlor

p,p'-Methoxychlor

trans-Permethrin

^a Selected water-quality standards and guidelines and sediment-quality guidelines (Gilliom and others, *in press*).

^b Rates of detection are based on the number of analyses and detections in the Study Unit, not on national data. Rates of detection for herbicides and insecticides were computed by only counting detections equal to or greater than 0.01 µg/L in order to facilitate equal comparisons among compounds, which had widely varying detection limits. For herbicides and insecticides, a detection rate of "<1%" means that all detections are less than 0.01 µg/L, or the detection rate rounds to less than 1 percent. For other compound groups, all detections were counted and minimum detection limits for most compounds were similar to the lower end of the national ranges shown. Method detection limits for all compounds in these tables are summarized in Gilliom and others (*in press*).

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GLOSSARY

Ammonia—A compound of nitrogen and hydrogen (NH₃) that is a common by-product of animal waste. Ammonia readily converts to nitrate in soils and streams.

Aquatic guidelines—Specific levels of water quality which, if reached, may adversely affect aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.

Aquifer—A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Atmospheric deposition—The transfer of substances from the air to the surface of the Earth, either in wet form (rain, fog, snow, dew, frost, hail) or in dry form (gases, aerosols, particles).

Background concentration—A concentration of a substance in a particular environment that is indicative of minimal influence by human (anthropogenic) sources.

Base flow—Sustained, low flow in a stream; ground-water discharge is the source of base flow in most places.

Basic Fixed Sites—Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of streamwater in relation to hydrologic conditions and environmental settings.

Basin—*See* Watershed.

Bed sediment—The material that temporarily is stationary in the bottom of a stream or other water course.

Benthic invertebrates—Insects, mollusks, crustaceans, worms, and other organisms without a backbone that live in, on, or near the bottom of lakes, streams, or oceans.

Carbonate—Rock or sediment composed of more than 50 percent carbonate minerals such as limestone or dolomite.

Clastic—Rock or sediment composed principally of broken fragments that are derived from preexisting rocks which have been transported from their place of origin, as in sandstone.

Combined sewer overflow—A discharge of untreated sewage and stormwater to a stream when the capacity of a combined storm/sanitary sewer system is exceeded by storm runoff.

Community—In ecology, the species that interact in a common area.

Concentration—The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as microgram per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

Denitrification—A process by which oxidized forms of nitrogen such as nitrate (NO₃⁻) are reduced to form nitrites, nitrogen oxides, ammonia, or free nitrogen: commonly brought about by the action of denitrifying bacteria and usually resulting in the escape of nitrogen to the air.

Detect—To determine the presence of a compound.

Detection limit—The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration.

Dieldrin—An organochlorine insecticide no longer registered for use in the United States. Also a degradation product of the insecticide aldrin.

Discharge—Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.

Drinking-water standard or guideline—A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Effluent—Outflow from a particular source, such as a stream that flows from a lake or liquid waste that flows from a factory or sewage-treatment plant.

EPT richness index—An index based on the sum of the number of taxa in three insect orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), that are composed primarily of species considered to be relatively intolerant to environmental alterations.

Eutrophication—The process by which water becomes enriched with plant nutrients, most commonly phosphorus and nitrogen.

Fertilizer—Any of a large number of natural or synthetic materials, including manure and nitrogen, phosphorus, and potassium compounds, spread on or worked into soil to increase its fertility.

Flood plain—The relatively level area of land bordering a stream channel and inundated during moderate to severe floods.

Fumigant—A substance or mixture of substances that produces gas, vapor, fume, or smoke intended to destroy insects, bacteria, or rodents.

Ground water—In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat—The part of the physical environment where plants and animals live.

Headwaters—The source and upper part of a stream.

Herbicide—A chemical or other agent applied for the purpose of killing undesirable plants. *See also* Pesticide.

Index of Biotic Integrity (IBI)—An aggregated number, or index, based on several attributes or metrics of a fish community that provides an assessment of biological conditions.

Insecticide—A substance or mixture of substances intended to destroy or repel insects.

Intensive Fixed Sites—Basic Fixed Sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.

Intolerant organisms—Organisms that are not adaptable to human alterations to the environment and thus decline in numbers where human alterations occur.

Intensive Fixed Sites—Basic Fixed Sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most

NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.

Karst—A type of topography that results from dissolution and collapse of carbonate rocks such as limestone and dolomite, and characterized by closed depressions or sinkholes, caves, and underground drainage.

Load—General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Macroinvertebrate—An animal that is large enough to be seen without magnification and has no backbone or spinal column.

Main stem—The principal course of a river or a stream.

Median—The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.

Micrograms per liter (µg/L)—A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Milligrams per liter (mg/L)—A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Nitrate—An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a plant nutrient and is very mobile in soils.

Nonpoint source—A pollution source that cannot be defined as originating from discrete points such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint source pollution.

Nonselective herbicide—Kills or significantly retards growth of most higher plant species.

Nutrient—Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Occurrence and distribution assessment—Characterization of the broad-scale spatial and temporal distributions of water-quality conditions in relation to major contaminant sources and background conditions for surface water and ground water.

Organic compound—A compound containing at least one carbon-carbon bond (C—C) or one carbon-hydrogen bond (C—H).

Organic detritus—Any loose organic material in streams—such as leaves, bark, or twigs—removed and transported by mechanical means, such as disintegration or abrasion.

Perched ground water—Water in an isolated, saturated zone overlying a layer of material with low hydraulic conductivity and separated from the main body of ground water by unsaturated sediment or rock. Perched ground water has a perched water table.

Pesticide—A chemical applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other "pests".

pH—The logarithm of the reciprocal of the hydrogen ion concentration (activity) of a solution; a measure of the acidity (pH less than 7) or alkalinity (pH greater than 7) of a solution; a pH of 7 is neutral.

Phenols—A class of organic compounds containing $\text{C}_6\text{H}_5\text{OH}$ and its derivatives. Used to make resins, weed killers, and as a solvent, disinfectant, and chemical intermediate. Some phenols occur naturally in the environment.

Phosphorus—A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Phthalates—A class of organic compounds containing phthalic acid esters [$\text{C}_6\text{H}_4(\text{COOR})_2$] and derivatives. Used as plasticizer in plastics. Also used in many other products (such as detergents, cosmetics) and industrial processes (such as defoaming agents during paper and paperboard manufacture, and dielectrics in capacitors).

GLOSSARY

Point source—A source at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.

Polychlorinated biphenyls (PCBs)—A mixture of chlorinated derivatives of biphenyl, marketed under the trade name Aroclor with a number designating the chlorine content (such as Aroclor 1260). PCBs were used in transformers and capacitors for insulating purposes and in gas pipeline systems as a lubricant. Further sale for new use was banned by law in 1979.

Polycyclic aromatic hydrocarbon (PAH)—A class of organic compounds with a fused-ring aromatic structure. PAHs result from incomplete combustion of organic carbon (including wood), municipal solid waste, and fossil fuels, as well as from natural or anthropogenic introduction of uncombusted coal and oil. PAHs include benzo(a)pyrene, fluoranthene, and pyrene.

Preemergence herbicide—Herbicide applied to bare ground after planting the crop but prior to the crop sprouting above ground to kill or significantly retard the growth of weed seedlings.

Postemergence herbicide—Herbicide applied to foliage after the crop has sprouted to kill or significantly retard the growth of weeds.

Recurrence interval—The average time interval between occurrences of a hydrologic event, such as a flood, of a given or greater magnitude.

Runoff—Excess rainwater or snowmelt that is transported to streams by overland flow, tile drains, or ground water.

Sanitary sewer overflow—A discharge of untreated sewage resulting from clogged sewer pipes or inoperative pumping stations. Untreated sewage overflows from manholes and leaky pipes into nearby streams rather than backing up into homes or businesses.

Selective herbicide—Kills or significantly retards growth of an unwanted plant species without significantly damaging desired plant species.

Semivolatile organic compound (SVOC)—Operationally defined as a group of synthetic organic compounds that

are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and Polycyclic aromatic hydrocarbons (PAHs).

Surface water—An open body of water, such as a lake, river, or stream.

Suspended sediment—Particles of rock, sand, soil, and organic detritus carried in suspension in a water column, in contrast to sediment that moves on or near a streambed.

Synoptic sites—Sites sampled during a short-term investigation of specific water-quality conditions during selected seasonal or hydrologic conditions to provide improved spatial resolution for critical water-quality conditions.

Tile drain—A buried perforated pipe designed to remove excess water from soils.

Total concentration—Refers to the concentration of a constituent regardless of its form (dissolved or bound) in a sample.

Trace element—An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Upland—Elevated land above low areas along a stream or between hills; elevated region from which rivers gather drainage.

Volatile organic compounds (VOCs)—Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

Watershed—The portion of the surface of the Earth that contributes water to a stream through overland run-off, including tributaries and impoundments.

Wetlands—Ecosystems whose soil is saturated for long periods seasonally or continuously, including marshes, swamps, and ephemeral ponds.

Yield—The mass of material or constituent transported by a river in a specified period of time divided by the drainage area of the river basin.

NAWQA

National Water-Quality Assessment (NAWQA) Program Apalachicola-Chattahoochee-Flint River Basin



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